MONTHLY WEATHER REVIEW

ALFRED J. HENRY, Editor

VOL. 52, No. 2
W. B. No. 829

FEBRUARY, 1924

CLOSED APRIL 3, 1924
ISSUED MAY 9, 1924

A CRUISE WITH THE INTERNATIONAL ICE PATROL

By ROBERT DE C. WARD

[Harvard University, October 16, 1923]

The Titanic memorial service.—On April 15, 1923, the United States Coast Guard cutter *Modoc*, on Ice Patrol duty, took up her position at the exact spot where the *Titanic* sank, after collision with an iceberg, 11 years before.[1] A radio message from the *Modoc* had been sent to the Associated Press on the night of April 14, asking that churches should join in a memorial service at 10 a. m. (eastern standard time) on the following day. All ships at sea were asked to hold services at the same hour. All radios were silent for five minutes, between 10 and five minutes after 10. Under these circumstances, with many thousands of men and women and children, on land and on the high seas, uniting in commemorating the great tragedy, the service was held on the quarterdeck of the *Modoc*. The American flag was at half-mast. Full military honors were paid to the dead.

This incident was one of extraordinary human interest and significance. The *Titanic* sank, as other "missing" vessels undoubtedly sank before her, in the years gone by, through collision with an iceberg. The loss of the giant White Star liner was a catastrophe which should never occur again. The *Modoc*, on Ice Patrol duty, lying-to over the grave of the *Titanic*, is a symbol of a high resolve that everything possible shall hereafter be done to prevent any such disaster in the years to come. To-day the danger zone is patroled day and night during the ice season. All passing ships are given full information about the location of menacing bergs. Radio broadcast ice reports are sent out twice a day from the Ice Patrol vessel. Special reports can be requested, and are immediately furnished at any hour, day or night. Trans-Atlantic passengers may now pass through the danger zone with a feeling of safety which they never could have before the patrol was established. They may sleep peacefully, knowing that a United States Coast Guard cutter, on Ice Patrol service, is doing her duty not far away. No serious collision with ice has taken place in the area covered by the patrol since that service was inaugurated.

Establishment of the International Ice Patrol.—The *Titanic* disaster led to the establishment of the Ice Patrol. One month after that catastrophe, the United States Hydrographic Office (May 15, 1912) made a recommendation to the Navy Department that one or more naval vessels should patrol in the vicinity of the steamer lanes and warn passing ships of ice danger. Such a patrol was at once put into operation, the U. S. S. *Birmingham* and *Chester* alternating on this duty during the1912 ice season. In 1913 the United States Revenue Cutter Service (now the Coast Guard) took over the task, the cutters *Seneca* and *Miami* alternating in the service, while the British S. S. *Scotia*, well known as an Antarctic exploring ship, cooperated and completed a valuable series of meteorological and oceanographic observations. In the autumn of 1913 an International Conference for the Safety of Life at Sea was held in London, as one result of which 14 maritime nations agreed (January 20, 1914) to maintain a continuous patrol of the area of the North Atlantic most endangered by ice during the ice season. The United States Government was asked to undertake the management of this service, and each of the contracting powers agreed to assume a share of the expense in proportion to its shipping tonnage. Since 1914, with the exception of 1917 and 1918, during the war, the Ice Patrol has been maintained during each ice season by the United States Coast Guard.

The United States Coast Guard and the United States Hydrographic Office cooperate in the administration and operation of the patrol. The former furnishes the ships and the men, while the latter disseminates the information collected by the patrol vessels to shipping interests, and also controls the shifting of the steamship tracks. Administrative matters are vested in a board composed of the Commandant of the Coast Guard, the Hydrographer of the Navy, the Director of the Bureau of Standards, the Chief of the Weather Bureau, and a member of the Fisheries Board. Dr. Henry B. Bigelow, of Harvard University, is an honorary member and scientific adviser. The Commandant of the Coast Guard is president of this board.

The life history of the icebergs in the danger zone.—The essential facts regarding the ice which menaces North Atlantic steamship traffic may be briefly stated. Most of the bergs come from the fringe of glaciers bordering the west coast of Greenland, east of Baffin Bay, and represent the wastage from the Greenland ice cap. (See fig. 1.)

A few come from the east coast of Greenland, round Cape Farewell, and travel north as far as Davis Strait before turning south in the Labrador Current. Others doubtless start in the Smith Sound region and even farther north. One glacier in west Greenland is reported to "calve" on the average one iceberg a day, and this record is probably equaled in other cases also. Once icebergs are afloat, and free to move, they start to drift under the influence of the currents and winds. Many doubtless never leave their home latitudes. Others, after drifting to and fro, find their way into the cold current flowing southward through Davis Strait, known farther south as the Labrador Current. Some of these become stranded off the Labrador coast. Others ground

[1] The *Titanic* sank on Apr. 14, 1912, in latitude 41° 46′ N., longitude 50° 14′ W. Over 1,500 lives were lost.

For the illustrations accompanying this article the writer is indebted as follows: Figs. 4-6 and 8, to Lieut. Commander William J. Wheeler; Figs. 3, 9, and 10, to Lieut. E. H. Smith; Fig. 7, to Chief Radio Man W. W. Reynolds. Figs. 2 and 3 are from the *Pilot Chart of the North Atlantic Ocean* for March, 1923.

on the northern slope of the Great Bank. Others move westward along the southern coast of Newfoundland. Relatively few eventually travel eastward and then southward toward the Tail of the Bank; and it is these which constitute the greatest danger to trans-Atlantic steamers while following the most-used steamer lanes. Here the interplay of the cold Labrador water and the warmer Gulf Stream water, resulting in a more or less complex month, and its track was carefully computed and plotted. The rate of drift of icebergs varies a good deal, a maximum of about 0.7 knot has been observed late in the season in the cold current around the Tail of the Bank. It has been estimated that if a berg keeps in the current, it will take it about five months to travel from Cape Dyer, Baffin Land, to south of latitude 45° N. Bergs do not long survive in the warm waters of the Gulf Stream,

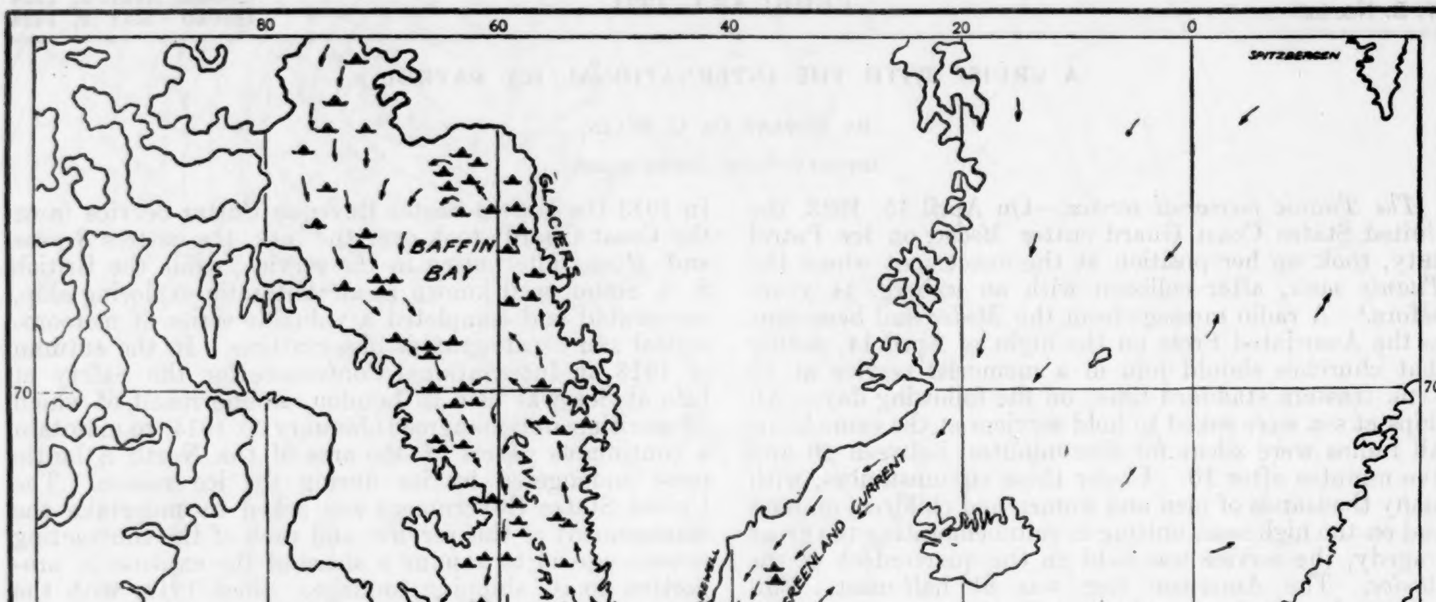


FIG. 1.—Map showing general drift of icebergs which may menace steamship tracks every spring

and varying series of eddies and currents, carries the bergs back and forth. Their courses, which often seem erratic, now appear, after careful study, to conform more or less to certain general rules. The typical drift of a large berg during the period from April 11 to May 12, 1921, is shown in Figure 2.

This berg was identified by means of photographs and in other ways; it was sighted four times during the

and they rarely drift more than a few miles south of its northern margin. Therefore the marginal region between the cold and the warm currents is the critical one for shipping, and it is the determination of the shifting boundary line between the safe and the unsafe areas which is one of the constant duties of the Ice Patrol. Hence the great importance of an accurate knowledge of the water temperature, in ascertaining which the

cooperation of all steamers in the danger zone is asked and expected. The dividing line between Labrador Current and Gulf Stream is often very sharply defined, not only by temperature, but also by the color of the water and by the "rips" which are seen, and felt, between the two currents. With the advance of summer, the iceberg-infested waters gradually become warmer; the Gulf Stream moves northward to the Tail of the Bank, and the ice season reaches its end. The regular steamer tracks between Europe and the United States are located to the south of the southern end of the Labrador Current, where that current is turned backward and eastward by the Gulf Stream at the Tail of the Bank (note drift of iceberg, April 21–May 12, fig. 2). Were the ice always in the same zone, the situation would be a simple one. The difficulty is that the number of bergs varies greatly from year to year, and that in some years they drift much farther southward than in others. It is on this account that the continued and regular work of the Ice Patrol is so important.

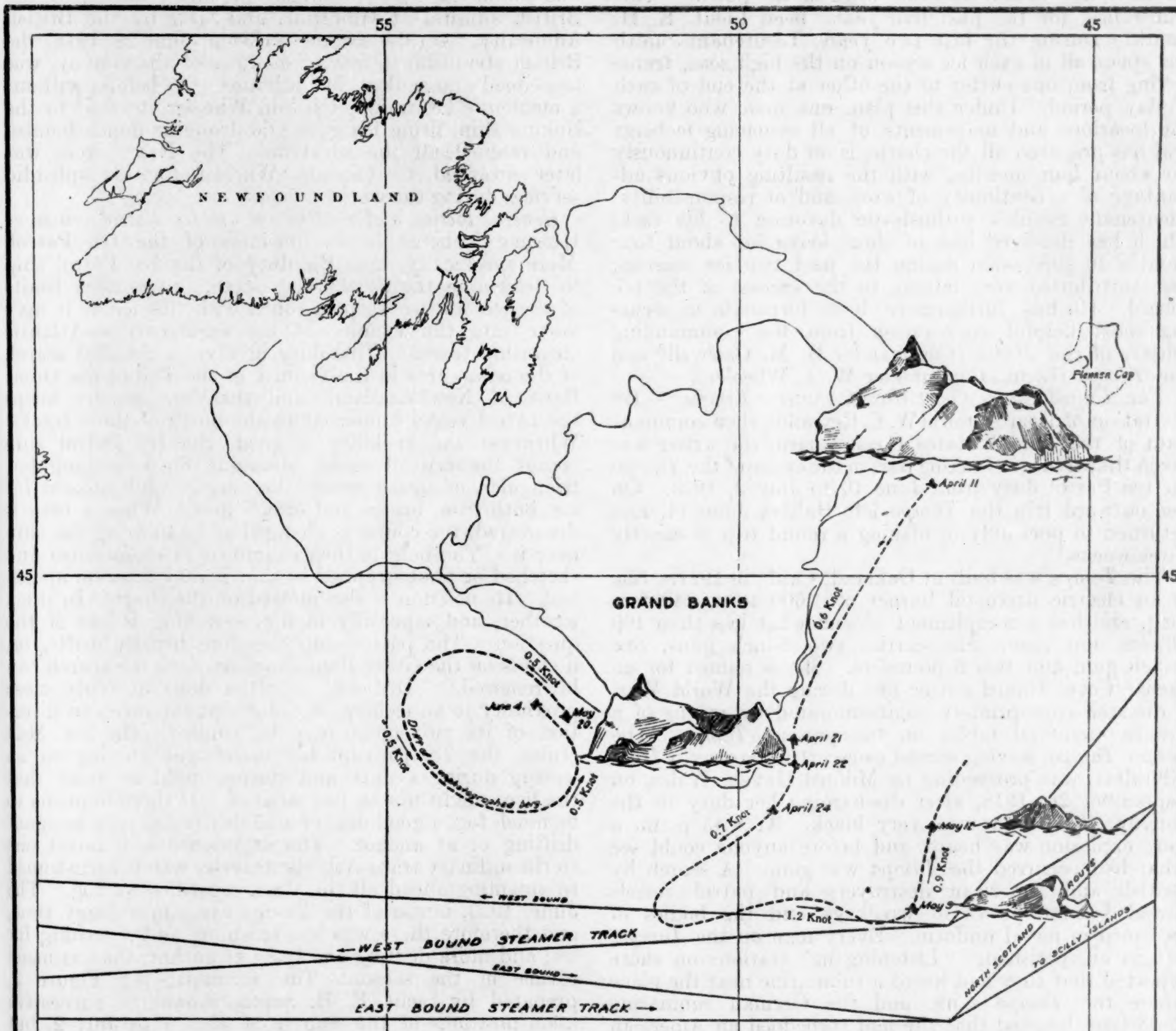


FIG. 2.—Map showing typical drift of an iceberg during the season of 1921

Organization of the International Ice Patrol.—To carry on the Ice Patrol the United States Coast Guard details each year two of its newest and best-equipped cutters. During the past two years the *Modoc* and the *Tampa*, sister ships, have been assigned to this important duty. From March through June, and into July if necessary,

these vessels base on Halifax, N. S., where they obtain fuel and supplies. They alternate in cruising in the ice region, the period of duty being 15 days on actual patrol, exclusive of the time occupied in going to and from Halifax. When the 15 days have expired, the vessel on patrol is relieved by the sister ship at sea. The relieving ship brings out the mail, and receives on board the officer in charge of the scientific work of the patrol. This officer has, for the past five years, been Lieut. E. H. Smith. During the last two years, Lieutenant Smith has spent all of each ice season on the high seas, transferring from one cutter to the other at the end of each 15-day period. Under this plan, one man, who knows the locations and movements of all menacing icebergs and has prepared all the charts, is on duty continuously for about four months, with the resulting obvious advantage of a continuity of work and of responsibility. Lieutenant Smith's enthusiastic devotion to his task, which has deprived him of shore leave for about four months in succession during the past two ice seasons, has contributed very largely to the success of the Ice Patrol. He has, furthermore, been fortunate in securing most helpful cooperation from the commanding officers of the *Modoc* (Commander B. M. Chiswell) and the *Tampa* (Lieut. Commander W. J. Wheeler).

The United States Coast Guard Cutter "Tampa."—By invitation of Rear Admiral W. E. Reynolds, then commandant of the United States Coast Guard, the writer was given the privilege of taking part in the cruise of the *Tampa* on Ice Patrol duty from June 16 to July 2, 1923. On her outward trip the *Tampa* left Halifax June 14, and returned to port July 5, making a round trip of exactly three weeks.[2]

The *Tampa* was built at Oakland, Calif., in 1921. She is an electric drive oil burner of 1,600 tons, 240 feet long, and has a complement of somewhat less than 100 officers and men. She carries two 5-inch guns, one 3-inch gun, and two 6 pounders. She is named for an earlier Coast Guard cutter lost during the World War, a disaster appropriately commemorated by means of a bronze memorial tablet on the present *Tampa*. The earlier *Tampa*, having served as escort for a convoy from Gibraltar, was proceeding to Milford Haven, Wales, on September 26, 1918, after discharging her duty to the convoy. The night was very black. At 8:45 p. m. a loud explosion was heard, and before anyone could see what had occurred the *Tampa* was gone. A search by British and American destroyers and patrol vessels revealed some pieces of wreckage and the bodies of two men in naval uniform. Every man on the *Tampa*, 115 in all, perished. "Listening in" stations on shore reported that they had heard a submarine near the place where the *Tampa* sank, and the German submarine *U-53* later boasted that she had torpedoed an American vessel answering to the description of the *Tampa*. This was the greatest single disaster which befell any American vessel during the war.

It is a satisfaction to note here that Lieutenant Commander Wheeler, of the new *Tampa*, has a splendid war record. On two occasions, when in command of the United States Coast Guard Cutter *Seneca*, acting as escort to a convoy between Gibraltar and the English Channel, he went to the rescue of the men on board of a torpedoed ship, although it was then the established rule that if a vessel had been torpedoed other vessels near by should keep away and not run the risk of being themselves torpedoed. On one of these occasions (April 25, 1918), although the sinking British sloop *Cowslip* signaled "Stay away; submarine in sight, port quarter," Captain Wheeler approached the *Cowslip* three times, lowered his boats, and took off all the men who had not been killed by the explosion. For this he was commended by Admirals Sims and Niblack, by the British admiral at Gibraltar, and later by the British Admiralty. On the second occasion (June 28, 1918) the British steamship *Queen*, a member of the convoy, was torpedoed and sank in five minutes. As before, without a moment's hesitation, Captain Wheeler steamed to the sinking ship, firing his guns and dropping depth bombs, and rescued all the survivors. The Navy cross was later awarded to Captain Wheeler for his splendid services during the war.

General tactics and routine on an Ice Patrol cruise.—Hunting icebergs is the business of the Ice Patrol. More specifically, it is the duty of the Ice Patrol ship to determine the southern, eastern, and western limits of the ice, and to keep in touch with this ice as it may move into the vicinity of the regular trans-Atlantic steamship tracks. This duty involves a detailed search of the ocean area in the vicinity of the Tail of the Great Bank of Newfoundland, and therefore usually keeps the patrol vessel somewhat to the north of these tracks. Whenever the visibility is good, the Ice Patrol ship combs the critical areas, steaming on a rectangular, triangular, or zigzag course, keeping careful lookout for ice, both from bridge and crow's nest. When a berg is discovered, the course is changed so as to bring the ship near it. The berg is then examined at close range and sketched or photographed so that it may later be identified. Its position is also plotted on the chart. In thick weather, and especially in fog, searching is out of the question. The patrol ship therefore usually drifts, or, if she is on the Great Bank, anchors until the search can be renewed. "Drifting" is often done in fairly close proximity to an iceberg, in order that the rate and direction of its movement may be studied. On her May cruise, the *Tampa* kept her searchlight playing on an iceberg during a dark and stormy night in order that the berg might not be lost sight of. If there happens to be much fog, a good deal of a 15-day cruise may be spent drifting or at anchor. The experience is a novel one to the ordinary trans-Atlantic traveler who is accustomed to steaming ahead all the time, regardless of fog. The June, 1923, cruise of the *Tampa* came in a foggy time, and therefore there was less steaming and searching for ice, and more drifting and lying at anchor, than is usual earlier in the season. The accompanying Figure 3, prepared by Lieut. E. H. Smith, shows the successive noon positions of the ship from June 7 to July 2, but does not attempt to give the very numerous varied courses which she followed during those days. It also shows the positions of the icebergs seen by or reported to the Ice Patrol cutter during that time.

Even when lying still, the Ice Patrol ship is a busy place. She is the clearing house for all information about ice. Every vessel passing through the ice region (between long. 43° and 55° W.) is expected to send by radio to the patrol vessel exact information as to any ice sighted, as well as four-hourly reports of water temperatures, and other data. As each vessel enters this area, her successive positions are plotted on board the patrol ship, so that her course may be followed stage by stage during her progress. If any passing steamer is seen to be in danger, a message is sent to her, informing

[2] The writer is under great obligations to the commanding officer of the *Tampa*, Lieut Commander William J. Wheeler, for unfailing courtesy and thoughtful attention throughout the cruise; to Lieut. E. H. Smith for most helpful interest and cooperation, and to the other officers of the ship for many favors.

her of the location of any neighboring berg, and advising a change of course. When a report comes in to the patrol ship of an iceberg not previously seen and charted, and in a dangerous position, a broadcast is at once sent out so that all vessels may be warned. At the same time the patrol ship immediately steams to the reported position of the new berg. Thus, on the *Tampa*, on two occasions during the June cruise such reports of ice led to the vessel's steaming a distance of 50 to 75 miles in order to investigate, and on one of these occasions the trip was made through dense fog. Again, inquiries often come in asking whether a certain vessel, following a certain course, is likely to meet ice. To all such questions immediate and full replies are sent. It not infrequently happens that vessels reporting ice give a position for the berg which is many miles out of the way, or even report a berg which careful search fails to reveal at all, and which may have been a distant cloud. Such wild-goose chases are well known on Ice Patrol duty.

In addition to the very numerous individual messages sent to passing ships, several regular broadcasts are sent out each day. Twice daily, at 6 a. m. and 6 p. m. (75th meridian time) a broadcast is sent to all vessels, giving full information regarding the position of all dangerous ice. Once a day, at 7 p. m. (75th meridian time), a message is sent to the Hydrographic Office in Washington

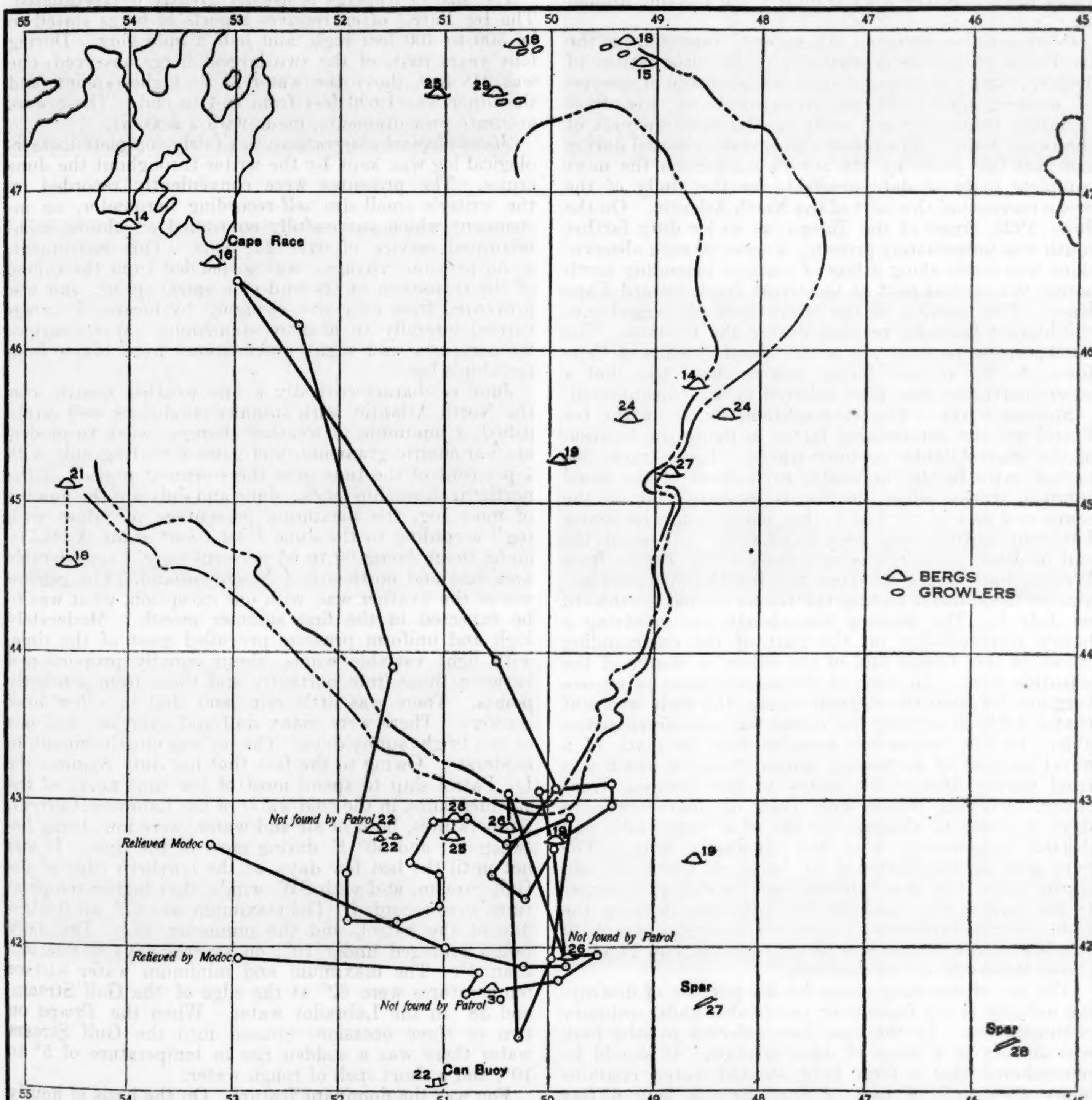


FIG. 3.—Noon positions and iceberg chart for the June, 1923, cruise of the *Tampa*

giving all essential facts as to ice and defining the ice danger zone.[3] Twice daily, at 7 a. m. and 7 p. m. (75th meridian time), a message is sent to the Weather Bureau in Washington, covering the regular meteorological observations. Without radio-telegraphy the Ice Patrol would be impossible. There are few busier places than the radio room on an Ice Patrol ship, and few places where more effective work is done toward saving human life.

Oceanographic stations.—At various times during the Ice Patrol season, as opportunity offers, observations of deep-sea temperatures and salinities are made at a series of oceanographic stations arranged along five lines radiating from a central point on the southern part of the Great Bank. The observations thus collected during the past few years by the Ice Patrol furnish the most complete body of data available for the study of the ocean currents of this part of the North Atlantic. On the June, 1923, cruise of the *Tampa*, as no ice duty farther south was immediately pressing, a series of such observations was made along a line of stations extending north across the central part of the Great Bank toward Cape Race. This portion of the cruise took the vessel into the highest latitudes reached during the 15 days. The northernmost position was within about 25 miles of Cape Race, N. F. It was during this northern trip that a severe northeast gale, later referred to, was encountered.

Steamer tracks.—The ice conditions found by the Ice Patrol are the determining factor in fixing the location of the trans-Atlantic steamer tracks. These tracks are moved extra far to the south, even south of the usual summer tracks, when the ice is especially far to the south and east of the Bank, thus lengthening the course but contributing very greatly to safety. Toward the end of June, a radio message reached the *Tampa* from Washington, asking whether the Ice Patrol would advise or recommend having the tracks shifted northward on July 1. The decision was clearly one involving a heavy responsibility on the part of the commanding officer of the *Tampa* and of the officer in charge of the scientific work. In view of the recent report of an iceberg not far from the steamer tracks, the reply was sent that a delay in shifting the tracks was considered advisable. In this connection mention may be made of a novel method of decreasing danger from ice which was tried during May, 1923, cruise of the *Tampa*. Guncotton wrecking mines were used on four successive days in order to shorten the life of a berg which had drifted dangerously near the steamship lanes. The berg was already softened by being in warm air and warm water, but it is believed that its end as a danger to navigation was hastened by fully two days as the result of the explosions. Figure 4 is a photograph of this berg while a mine was being exploded, and Figure 5 shows the result of the explosion.

The use of wrecking mines for the purpose of destroying icebergs is not feasible or practicable under ordinary circumstances. In the case here referred to, the berg was already in a stage of disintegration. It should be remembered that a large berg, in cold water, contains many thousands of tons of hard ice. A berg 65 feet high and 1,690 feet long, seen by the *Tampa*, was calculated to contain approximately 36,000,000 tons of ice. The destruction of such a mass is obviously quite beyond human power, especially under the conditions obtaining at sea.

Some typical icebergs.—Through the kindness of Lieut. Commander William J. Wheeler, commanding officer of the *Tampa*, and of Lieut. E. H. Smith, it is possible to include several views of icebergs taken during recent cruises of that vessel.

The size of icebergs is usually greatly overestimated. The Ice Patrol often receives reports of bergs stated to be 300 to 400 feet high, and half a mile long. During four years past, of the two largest bergs observed, one was 248 feet above the water at its highest point, and the other was 1,690 feet from end to end. These were accurate measurements, made with a sextant.

Meteorological observations.—A fairly complete meteorological log was kept by the writer throughout the June cruise. The pressures were conveniently recorded on the writer's small-size self-recording barometer, an instrument which successfully continued an almost uninterrupted service of over 25 years. This instrument, as on previous voyages, was suspended from the ceiling of the stateroom at the end of a spiral spring, and was prevented from excessive swinging by means of strings carried laterally to near-by stanchions. Water-surface temperatures and night observations were taken from the ship's log.

June is characteristically a fine weather month over the North Atlantic, with summer conditions well established, a minimum of weather changes, weak to moderate barometric gradients, and gales occurring only 5 to 7 per cent of the time over the stormiest portion of the northern steamship lanes. June and July are the months of most fog, the maximum percentage of "days with fog" according to the June *Pilot Chart of the North Atlantic Ocean* being 60 to 65 per cent over a considerable area east and northeast of Newfoundland. The general run of the weather was, with one exception, what was to be expected in the first summer month. Moderately high and uniform pressure prevailed most of the time, with light variable winds, about equally proportioned between those from northerly and those from southerly points. There was little rain, and that in a few brief showers. There were many dull and overcast, and one or two bright sunny days. The sea was mostly smooth to moderate. Owing to the fact that her duty requires the Ice Patrol ship to spend most of her time north of the steamer lanes, in the cold water of the Labrador Current, temperatures, both of air and water, were low, being between 40° and 50° F. during most of the time. It was not until the last few days, at the northern edge of the Gulf Stream, and with SW. winds, that higher temperatures were recorded. The maximum was 67°, on the last day of the patrol, and the minimum 38.° The daily range averaged under 10°; on several days it was less than 5°. The maximum and minimum water surface temperatures were 62° at the edge of the Gulf Stream, and 38° in the Labrador water. When the *Tampa* on two or three occasions crossed into the Gulf Stream water there was a sudden rise in temperature of 5° to 10°, and a short spell of rough water.

Fog was the dominant feature. On the basis of hourly observations fog of varying degrees of density prevailed nearly 70 per cent of the time, an average somewhat above that shown on the Pilot Chart for the same area (about 50 per cent). The fogs of the Bank are generally known to be most prevalent with light to gentle southerly (S., SE., SW.) winds, when warm moist air from the Gulf Stream drift is carried across the cold Labrador water. The conditions on the present cruise

[3] A sample of such a report is the following: "Our position, lat. 40° 33', long. 48° 20'; three bergs within radius of 5 miles. Fog shrouds them at times; very dangerous to westbound traffic. A few bergs along east side of Great Bank and around tail. One berg, lat. 42° 52', long, 49° 51'; one berg, lat. 42° 42', long 49° 42'; one berg, lat. 48° 07' long. 45° 55'. Many bergs between Flemish Cap and Great Bank. Fifty growlers northeast of Cape Race."

FIG. 4.—Shortening the life of an iceberg by means of a wrecking mine

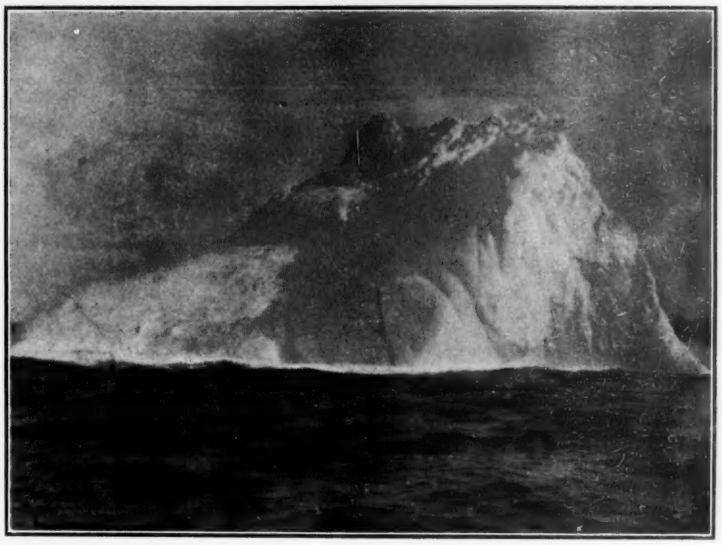


FIG. 7.—A massive iceberg, waterworn near the surface

FIG. 5.—The result of explosions in breaking up an iceberg

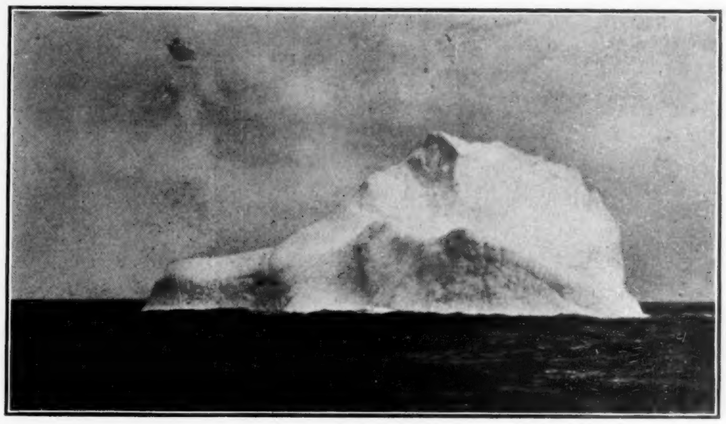


FIG. 8.—A berg well smoothed by wave action and by melting

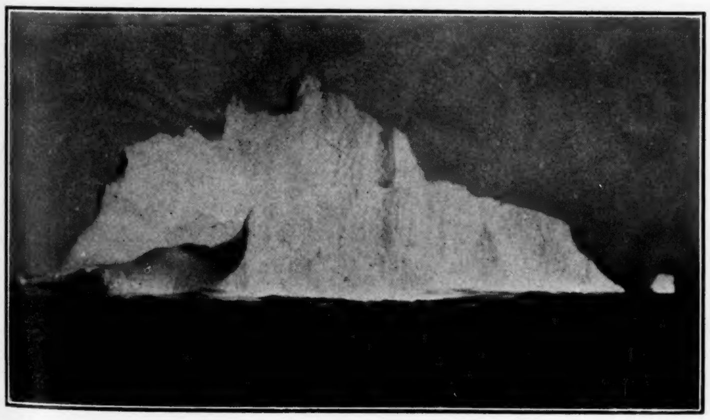


FIG. 6.—Iceberg with two vertical faces and a small "growler"

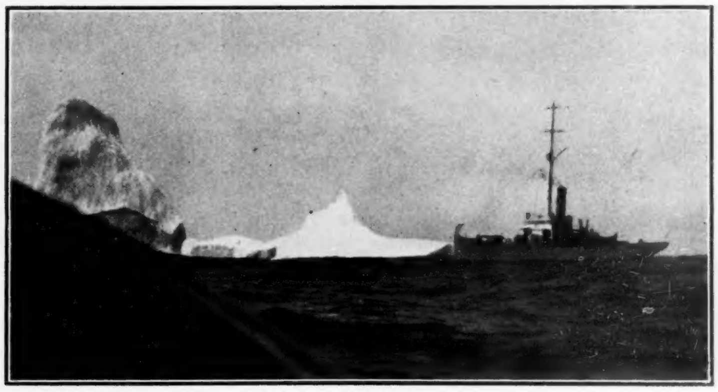


FIG. 9.—The *Tampa* lying close to a small berg

FIG. 10.—A small berg, well waterworn and melted, looking aft on the *Tampa*

were in agreement with this fact, but considerable fog also occurred with NE., N., and NW. breezes. The question arises whether northerly winds are not more likely to be foggy in summer, when they are warmest, rather than during the colder months.

In order to study the vertical distribution of temperature in fogs, several sets of simultaneous observations were secured on the lower deck and in the "crow's nest," about 12 feet and 90 feet above the water line, respectively. These observations were made when the wind was southerly in the morning and also about sunset, during dense fogs which extended vertically above the "crow's nest." The temperatures at 90 feet were 4° to 5.5° higher than those on the deck, the surface water being 4° to 15° colder than the air 12 feet above it. Inversions averaging about 5° in 78 feet were thus found, or about 1° in 15 feet. The marked chilling of the air in close contact with the cold water is clearly seen in these observations.

An interesting phenomenon was observed on a late afternoon near the northern margin of the Gulf Stream. The ship herself was in a clear area, while around the horizon lay fog banks, their upper surfaces being clearly defined against the western sky. At frequent intervals wisps, streamers, columns, and often larger masses of fog rose above the general level top of the fog banks. Several of these rising portions resembled waterspouts, and might easily have been mistaken for them. Others, more massive, looked like distant mountainous islands. Others again might readily have been recorded as icebergs. Careful observations from the bridge, both with the naked eye and with marine glasses, showed a slow spiralling or vortex motion in some of the smaller and more slender forms of these fog growths. It appeared as if this phenomenon were due to a convectional ascent induced by the vertical temperature gradient between the lower air, lying on the warm water, and the colder air at the top of the fog banks, cooled by radiation at sunset. An eddying motion might easily be produced under such conditions. The surface wind at the time was very gentle, and the lower clouds gave no indication of a rapid movement of the air a short distance aloft. Hence there seemed little opportunity for a rolling-over and intermingling of surface and upper air currents.

The only marked atmospheric disturbance occurred during about 36 hours while the *Tampa* was running across the Bank toward and from Cape Race. Pressures fell from 30 inches to 29.15 inches in 18 hours (barograph readings). Fresh NE. gales, reaching a force of 10 Beaufort, blew for several hours, with a very rough sea and some rain squalls. The clinometer in the engine room showed a maximum roll of 46°. As the *Tampa* was making slow progress against the gale and heavy sea, and had suffered damage to one of her boats, she was put about and headed south, before the wind. With a rising barometer, the wind backed to the NW., with slowly diminishing force and a clearing sky. A radio report from Cape Race reported a wind velocity of 63 miles an hour at that station. This was undoubtedly exceeded on the *Tampa*. The weather broadcast from Arlington noted "a disturbance of considerable intensity central immediately south of Newfoundland moving slowly northeastward." Confirmatory evidence of this fact was found in reports received on the *Tampa* from other vessels in the general vicinity but farther south, as well as in the observations made on the *Tampa* herself, which apparently passed nearly through the center of the disturbance, and somewhat to the north of it. The rear of the cloud sheet was clearly seen retreating to the eastward on the following day.

The highest pressures (30.45 inches) occurred during a well-marked anticyclone which prevailed throughout the last few days of the *Tampa's* Ice Patrol duty. A report of an iceberg not far from the steamer lanes, south of the tail of the Bank, had led to a quick run to the southward. For three or four days the vessel "drifted" most of the time, lying a little north of the steamer lanes near the northern edge of the Gulf Stream, in a dense fog, with a very smooth sea, variable breezes, mostly southerly and southwesterly, and calms; temperatures running between 60° and 70°. These were "typical" conditions for fog. No search for ice was possible during this spell.

Although, as stated above, the patrol ship spends most of her time in the cold water, she occasionally runs across the so-called "Cold wall" into the Gulf Stream. The contrast between the cold greenish Arctic water and the warm bluish Gulf Stream water is sometimes very clearly seen, as was the case on the return voyage of the *Tampa* to Halifax early in July, 1923. On one occasion, in 1922, when the ship was placed directly across the "Cold wall," the water temperature at the bow was 34°, and at the stern 56°. On a fine day in June, 1922, swimming liberty was granted to all hands. The men dove off the ship into water at a temperature of 70°, while within a half mile to the northward there was an iceberg.

Daily weather maps based on radio reports.—Through the generous cooperation of Chief Radio Man Reynolds of the *Tampa* it was possible to construct synoptic weather maps for the eastern United States based on the regular Weather Bureau observations broadcast from Arlington. With a few exceptions, a map was drawn every morning on the basis of the 8 p. m. (75th meridian time) observations, and on most days a second map, based on the 8 a. m. observations, was also constructed. In addition to the land stations regularly included in the broadcast, reports from vessels at sea received by the *Tampa*, as well as the observation made on the *Tampa*, were also used in preparing these maps. The construction and study of the maps proved most interesting, not only from the point of view of the weather conditions prevailing at home, but also because of their use in making general forecasts for the western North Atlantic. Such forecasts were made daily on board by the writer, and were not without interest and value. The development and the later break-up over the eastern United States of the hot wave of the third week of June was carefully watched on these daily maps constructed at sea. The Associated Press broadcasts received on the *Tampa* reported, as was expected, many deaths from sunstroke and thousands of heat prostrations within the hot-wave area. At sea during these same days the temperatures were between 40° and 50°, heavy clothing was being worn, and steam heat was turned on in the cabins. The passage eastward down the St. Lawrence Valley, or farther to the south, of several depressions was also watched with interest with reference to their possible control over the weather at sea. With one exception, however, these June cyclonic areas were too weak, and passed too far to the northward, to cause any appreciable disturbance over the area of the *Tampa's* cruising. Conditions in the eastern United States favorable for heat and for wind-shift line thunderstorms were readily picked out, even on the incomplete maps constructed on shipboard

With regard to the use, in the construction of daily weather maps at sea, of meteorological observations

received from other vessels, the writer's own experience leads to his making the following suggestions. Under the present plan, all vessels in the danger zone are expected to report to the Ice Patrol ship regularly every four hours their position, course, speed, and water surface temperatures. These reports vary greatly in their completeness and accuracy. There is diversity as to the hours of observation and often extreme uncertainty as to what time is used, whether G. M. T. (Greenwich mean time), or ship's local time, or 75th meridian time. Some vessels report barometer reading, wind direction and force, weather, state of sea, etc., while others do not. Further, a study of the barometer readings reported to the *Tampa* showed beyond question that these were often considerably in error, and therefore not comparable, or of value in drawing a synoptic map. These difficulties in the pressure readings probably result from (1) instrumental errors, (2) differences in elevation above sea level (3) carelessness in observation, and (4) other causes. If it is desirable that regular daily weather maps should be properly constructed on board the Ice Patrol ships, and that such maps should become of real use in forecasting at sea, it is suggested that definite arrangements be made with the regular passenger lines whereby two of the usual four-hourly observations now requested should always be made at 8 a. m. and 8 p. m., 75th meridian time (G. M. T., 1 a. m. and p. m.), in order that they may synchronize with the Weather Bureau broadcasts; that the ship's barometers should frequently be compared with a standard, and the corrections determined; and that greater care should be taken in making all the observations. The complete record, to be sent to the Ice Patrol ship at 8 a. m. and 8 p. m. (75th meridian time) in systematic and regular order, would be as follows: Name (letters) of vessels; time (G. M. T., given in a four-figured group of numerals, starting with 0000 at midnight); latitude; longitude; course; speed; surface water temperature; air temperature; barometer (reduced to sea level); wind direction and force; fog (yes or no); remarks. This same scheme might naturally well be followed in sending the regular four-hourly reports already asked for by the Ice Patrol.

Icebergs seen during the cruise.—Although the June cruise of the *Tampa* came just at the end of the 1923 ice season, several icebergs dangerous to navigation were seen at very close quarters. Two of them were of a common type; low, elongated and well water-worn masses, without pinnacles or vertical sides, and of a general "saddleback" form. One had two distinct "streaks" of dirt in it, and showed a well-marked fissure extending from top to bottom, filled with a more bluish ice than that of the berg itself. The second, with many distinct water-worn gullies on its surface, showed a former sea-level erosion line tilted up at an angle of nearly 90°, indicating that the berg had lately shifted its position by that amount. A rough calculation gave a weight of about 30,000 tons to the larger of these two bergs. The other bergs were of the pinnacled type. A small one had a height of about 75 feet and a length of 200 feet and had apparently lately split through, as one end presented a sheer vertical face from top to bottom. This berg could be seen long after the *Tampa* had left it, far away on the horizon, reddened by the rays of the setting sun. The largest berg was 170 feet high from the ocean surface to its topmost pinnacle, as determined by angular measurements from the bridge. From its highest peak it sloped symmetrically toward its lowest point. On one side there was a sheer vertical face from top to bottom. This last berg was by far the largest, most majestic and most impressive which was seen. All the bergs had numbers of small "growlers" drifting near them.

General impressions of the cruise.—Many incidents come to mind as the writer recalls his cruise of 15 days on the Ice Patrol: the first iceberg seen on a cold grey day before sunrise, sullen, massive, forbidding; the numerous drills of the men; the fresh cod caught while the vessel was at anchor on the Bank; the friendly conversations carried on by radio with the Cape Race and the St. Pierre operators craving human contact and sympathy at their lonely posts of duty; the urgent call for medical aid for a new-born baby on Sable Island, the "graveyard of the Atlantic," which came when the *Tampa* was over 200 miles away, drifting in a dense fog in the probable vicinity of ice; her immediate start for Sable Island, through the fog, on her errand of mercy; the relief experienced by all hands when a later message reported the baby better and no longer in need of help; the Fourth of July National salute at sea in a thick fog, on the westward course back to Halifax. But the outstanding thought is the splendid work which is being done, year after year, quietly and unostentatiously, amid the dangers of ice and storm, by the faithful officers and men of the United States Coast Guard on Ice Patrol.[4]

[4] Fuller details concerning the work of the Ice Patrol and the movements of the ice may be found in the following: Edward H. Smith (lieutenant, United States Coast Guard), "Some meteorological aspects of the ice patrol work in the North Atlantic," MONTH. WEA. REV., December, 1922, pp. 629–631, and "Practical knowledge regarding iceberg drifts for trans-Atlantic navigators," *Pilot Chart of the North Atlantic Ocean*, March, 1923, U. S. Hydrographic Office. The writer acknowledges his indebtedness to Lieutenant Smith's articles, from which many of the facts here given were obtained, and from which two charts (figs. 1 and 2) were taken.

LOCAL FORECAST STUDIES—WINTER PRECIPITATION

By THOMAS ARTHUR BLAIR, Meteorologist

[Weather Bureau, Honolulu, Hawaii, January 5, 1924]

In a previous paper [1] occurrences of precipitation during the summer months, May to August, inclusive, at Dubuque, Iowa, were tabulated with reference to the meteorological conditions obtaining at the previous regular morning observation at 7 a. m., 90th meridian time, and the percentage of days with rain under varying conditions shown in a series of curves. In the present paper a similar study is made of the relation between local meteorological conditions and the subsequent precipitation during the winter months, also at Dubuque, Iowa; latitude 42° 30′, north; longitude 90°, 44′, west; elevation 698 feet.

The data used are for the winter months, November, December, January, and February, for the 33-year period, 1889 to 1921, inclusive, with some omissions due to interrupted record, making a total of 3,606 observations. The method employed is that of the previous paper, namely, the construction of a series of curves, "showing the relation, expressed as a percentage, which the number of observations followed by rain in 12 or 24 hours bears to the total number of observations" within the various groups. To facilitate comparison with summer conditions, Figures 1, 2, and 3, have been made directly comparable with Figures 1, 2, and 6 of the earlier paper and include traces of precipitation and days when precipitation was occurring at observation.

The total probability of rain under all conditions is 0.34 within 12 hours and 0.45 within 24 hours. For the summer months the corresponding probabilities were 0.31 and 0.46, respectively.[2] Decreasing probability with increased barometric height is well shown in the "all observations" curves of Figures 1 and 2, but even with very high pressures there is considerable probability of rain, provided the pressure is decreasing. The downward tendency of the curves for pressures above 30.15 inches is much less marked in winter than in summer. With cloudy weather and falling pressure the percentages are continuously above 50 and rise to 80 for the 12-hour period and 84 for the 24-hour period. A distinct secondary maximum occurs with falling barometer at pressures between 30.25 and 30.34, at a point where, in summer, the chances are rapidly and steadily decreasing to negligible values. With cloudy weather and falling pressure the percentage within 12 hours rises to 78, which is within 2 per cent of that at the lowest pressures. As will be shown later this maximum is much less marked when traces are omitted from consideration. These characteristics of the curves describe the fact, which I think is generally recognized, of the high probability of light snowfall within 12 hours when the barometer is high but has begun to fall.

With clear weather and rising pressure the probability varies between 0.22 and 0.06 for 12 hours, and between 0.34 and 0.17 for 24 hours. It is least when the temperature is also rising. Consistently, at the other extreme, the probability is greatest with falling temperature, combined with falling pressure and cloudy skies. This latter is true only for pressures below 29.84 inches. Above that point the temperature relation seems doubtful, the curves crossing each other three times. The corresponding curves for the summer data were less consistent, both the highest and the lowest probabilities occurring with falling temperature.

Figure 3 is comparable with Figure 6 of the previous paper, and similarly shows that temperature changes alone afford no basis for rain prediction. It will be noted that a rapid fall in pressure is a much less reliable indicator of rain in winter than in summer. In summer a barometric decline of 0.25 inch within 12 hours is practically certain to result in rain in the following 12 hours, but in winter the same pressure change is followed by rain within 24 hours less than two-thirds of the time.

There is no forecasting value, however, in including days when rain is falling at the time of observation, as has been done in the above discussion, since they must all be recorded as having rain within the following 12 hours, and traces of precipitation have little practical significance. Omitting the former observations entirely, and counting as days with rain only those which have 0.01 inch or more, the total probability of rain within 12 and 24 hours, respectively, is reduced from 0.34 and 0.45 to 0.11 and 0.22. The contrast is clearly seen by comparing Figures 1 and 2 with Figures 5 and 6. In order to bring out more clearly the frequent occurrence of insignificant amounts of precipitation, Figure 4 was prepared, showing that during the winter months in fully one-half of the cases in which precipitation is recorded the amount of moisture received is too small to measure.

Under none of the combinations shown in Figures 5 and 6 are there as much as even chances of rain, the highest percentage found being 48. As previously mentioned, the marked secondary maximum of Figures 1 and 2 at pressures between 30.25 and 30.34 becomes much less pronounced when traces are omitted, but in the latter case another secondary maximum develops at pressures between 29.95 and 30.04, which, indeed, with cloudy weather and falling barometer, becomes the primary maximum for the 24-hour period. With rising pressure the primary maximum is at the next lower level of pressure, 29.85 to 29.94. It appears, then, that a measurable amount of snow is more apt to follow median pressures, whether the tendency be upward or downward, than very low ones, while traces are more frequent with distinctly low or distinctly high pressures.

The downward slope of the curves with rising pressure is even less in Figures 5 and 6 than in Figures 1 and 2. Figure 6 plainly says that the actual height of the barometer in winter affords little indication of the chances of rain, little at least as compared with its indications in summer. Neither does change in pressure, as shown in Figures 7 and 8, give a very accurate forecast. The slope of the lines is more consistent, but the range of probabilities is not great. A rapid fall of the barometer is followed by measurable precipitation in winter less than one-third of the time, but by flurries or traces about two-thirds of the time.

We find more definite indications when we consider the relations of wind direction to precipitation, Figure 9, and for the first time discover a condition under which the odds in favor of a measurable amount of rain are better than one to one. With an east wind and falling pressure, it has rained within 24 hours in 62 per cent of the cases. With falling pressure the probability of rain is distinctly greatest with wind from the east, i. e., with a center of low pressure slightly south of west and a center of high pressure slightly north of east. In the previous article

[1] Blair, T. A., Local Forecast Studies-Summer Rainfall, Mo. WEA. REV., April, 1921, 49: 183-190.

[2] "Rain" and "rainfall" are used to include all precipitation, much of which is snow during the months under consideration. "Probability" is used as equivalent to percentage, not calculated by the more exact formula, $p=\frac{m+1}{n+2}$.

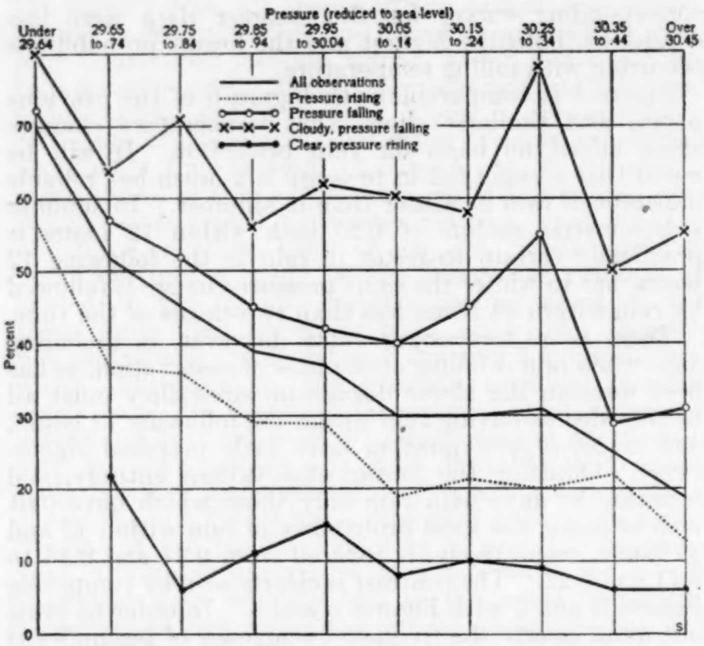


FIG. 1.—Percentage of observations followed by rain within 12 hours, as related to height of barometer and other factors. Days with trace and with rain falling at observation included. Based on 3,606 observations at Dubuque, Iowa

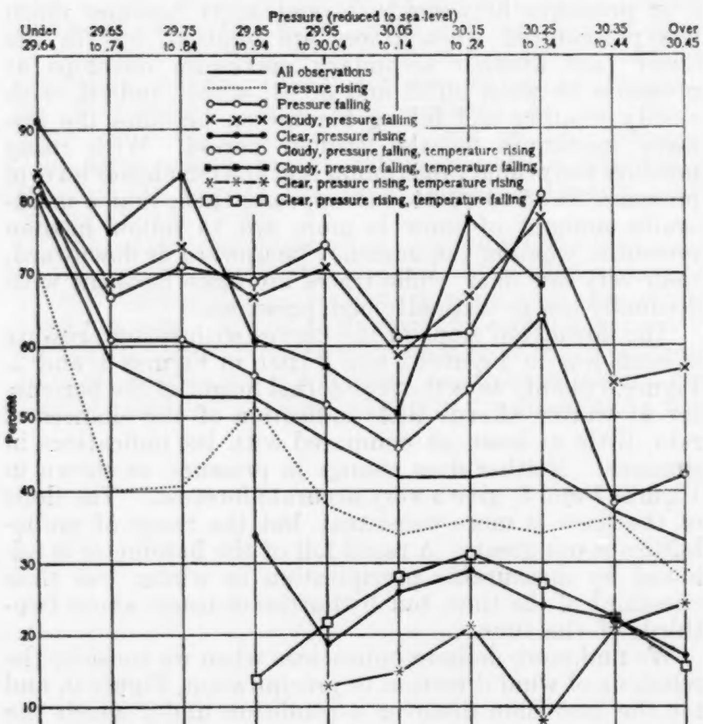


FIG. 2.—Percentage of observations followed by rain within 24 hours, as related to height of barometer and other factors. Days with trace and with rain falling at observation included. Based on 3,606 observations at Dubuque, Iowa

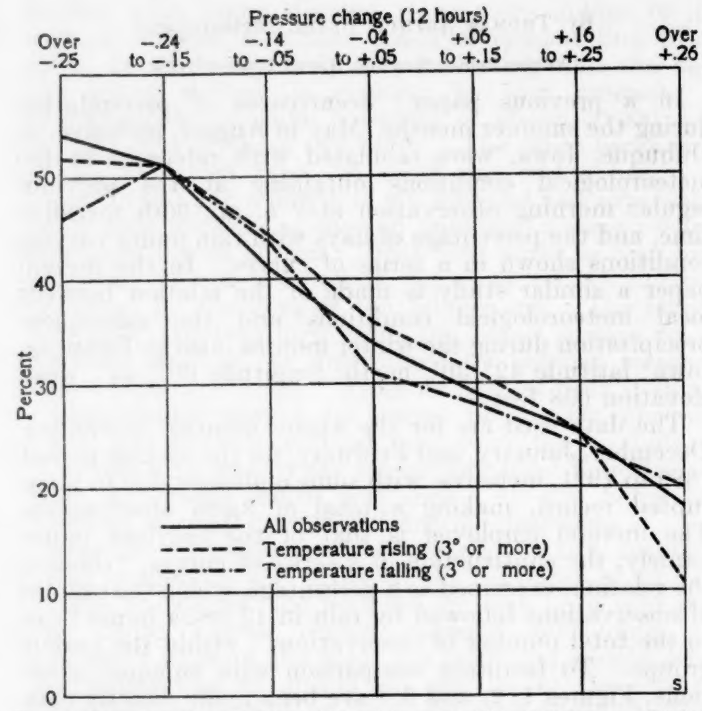


FIG. 3.—Percentage of observations followed by rain within 24 hours, as related to changes in pressure and temperature. Days with trace and with rain falling at observation included; 3,603 observations

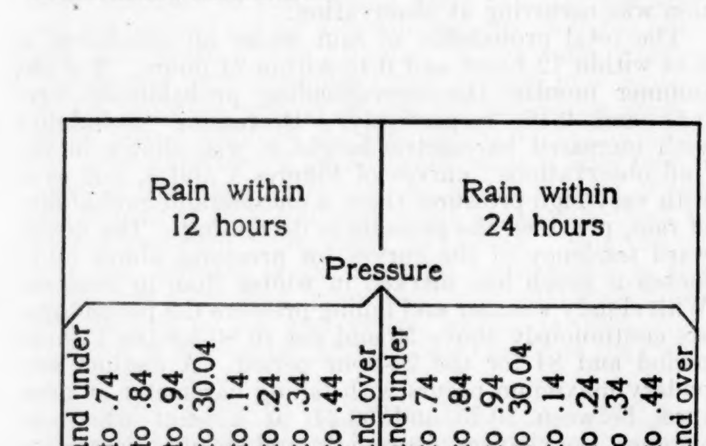


FIG. 4.—Percentages of traces in total number of occurrences of precipitation at Dubuque, Iowa, during the winter months. Number of observations, 856 for 12-hour period; 1,274 for 24-hour period

the same condition was found to obtain for the summer months. With rising pressure rain is most probable with a northeast wind, i. e., the LOW is moving eastward south of the station and pressure is rising in the north and northeast. In summer this pressure distribution is distinctly dry and the reverse conditions are those most favorable for rain with rising pressure. Instead of northeast it is southwest winds that give the highest summer frequency, the station being in the southwest quadrant of a barometric depression and the rainfall being mostly due to thunderstorms. In winter, winds with a westerly component are very dry under all conditions, and the contrast between the probabilities with easterly and those with westerly winds is much sharper than in summer.

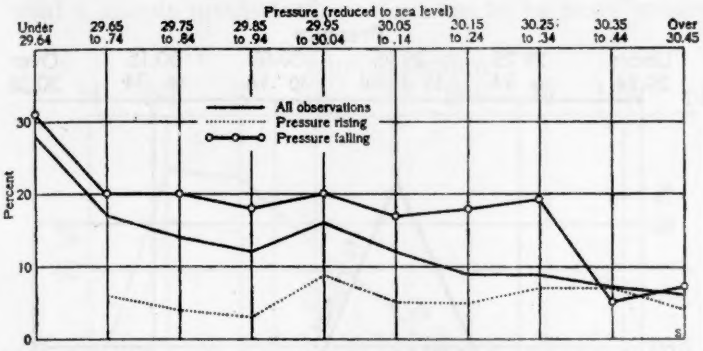


FIG. 5.—Percentage of observations followed by 0.01-inch or more of precipitation within 12 hours, as related to pressure and pressure change. Days with rain falling at observation omitted. Based on 3,246 observations at Dubuque, Iowa

The relation between kind of clouds and subsequent precipitation is shown in Table 1. The probability under most conditions is highest with dense fog and with stratus clouds, and lowest with no clouds, but is also distinctly low on the average with cumulus and alto-cumulus clouds.

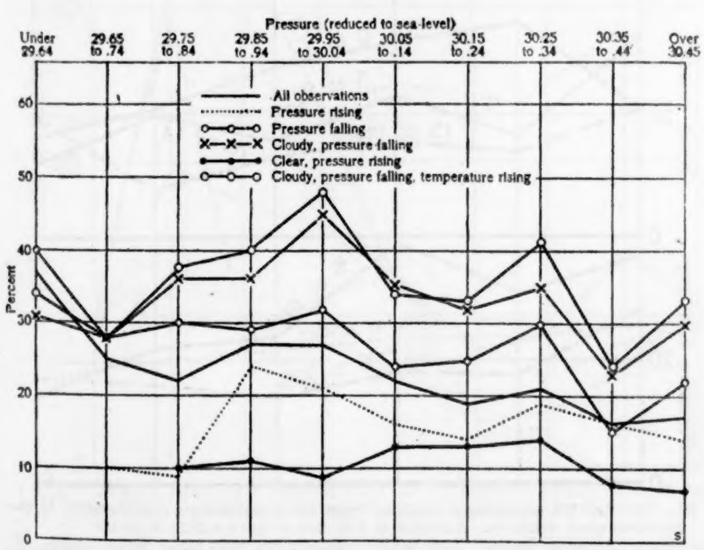


FIG. 6.—Percentage of observations followed by 0.01-inch or more of precipitation within 24 hours, as related to pressure, pressure change, and cloudiness. Days with rain falling at observation omitted. Based on 3,246 observations at Dubuque, Iowa

However, with alto-cumulus accompanying a rising barometer the chances of rain within 12 hours are not only relatively good but are absolutely higher than when the barometer is falling. With falling pressure cirro-cumulus and strato-cumulus clouds are frequent precursors of rain. These results are consistent with those described for France by Schereschewsky and Wehrlé [3] in their recently published and illuminating discussion of cloud systems. In their typical cloud system associated with a center of falling pressure, cirro-cumuli directly precede the center of the system, and are therefore in an area of falling pressure generally followed by rain, while alto-cumuli with falling pressure are found on the extreme margin

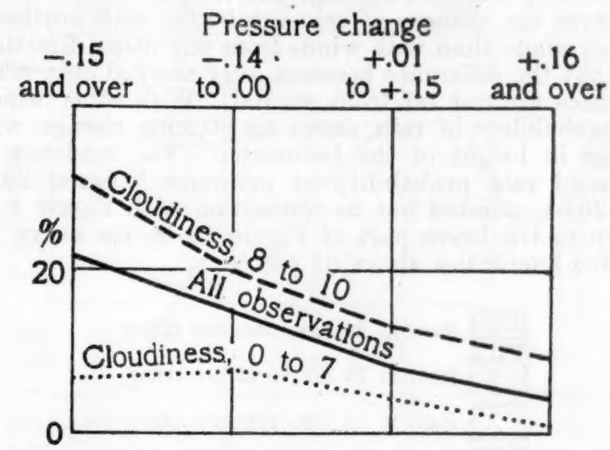


FIG. 7.—Percentage of observations followed by 0.01-inch or more of precipitation within 12 hours, as related to pressure change and cloudiness; 3,132 observations

of the system, where rain is infrequent, but alto-cumuli with rising pressure occur in the train of the system, where showers or patches of rain are frequent.

It has never rained within 12 hours when cumulus clouds and rising pressure were observed at the morning observation, fully justifying the expression, "fair weather cumulus;" but for falling pressure or for a 24-hour

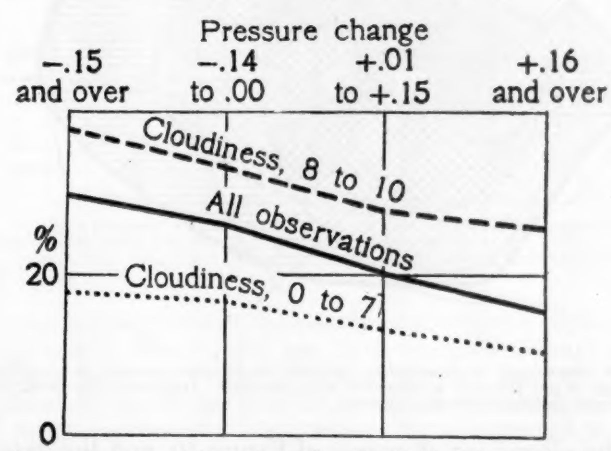


FIG. 8.—Percentage of observations followed by 0.01-inch or more of precipitation within 24 hours, as related to pressure change and cloudiness; 3,132 observations

period with rising pressure the frequency of rain following cumulus clouds is about the average of all observations. A contrast appears between summer and winter fogs. In summer the probability of rain following dense fog was found to be less than the average probability, but in winter dense fogs surpass any other cloud conditions as indicators of rain in three of the four columns of Table 1. The different nature of summer and winter fogs in this region was pointed out by Martin.[4] He classed summer fogs as local radiation phenomena and winter fogs as advective, due to air movement. In the Dubuque data 65 per cent of the summer fogs occur with rising pressure, and 54 per cent of the winter fogs with falling pressure.

[3] Schereschewsky and Wehrlé, Les Systèmes Nuageux, Office National Météorologique de France, 1923.

[4] Martin, H. H., Fog in central Ohio and its relation to subsequent weather changes, MO. WEATHER REV., July, 1919, 47: 471-472.

In the study of the probabilities of rain resulting from the simultaneous consideration of two meteorological elements certain further relationships are brought out by Tables 1, 2, and 3, and Figures 10 and 11. Both tables and figures are in the form used by Rolf[5] in his study of Swedish data along these lines. The upper set of curves in Figure 10 brings out the fact that with all pressures the chances of rain are better with northeast to east winds than with winds from any other direction, but that the difference becomes very marked only when pressures are not far from normal. With other winds, the probability of rain shows no striking change with change in height of the barometer. The tendency to increased rain probability at pressures between 29.95 and 30.04, pointed out in connection with Figure 6, is shown in the lower part of Figure 10, in the curve for relative humidities above 91 per cent.

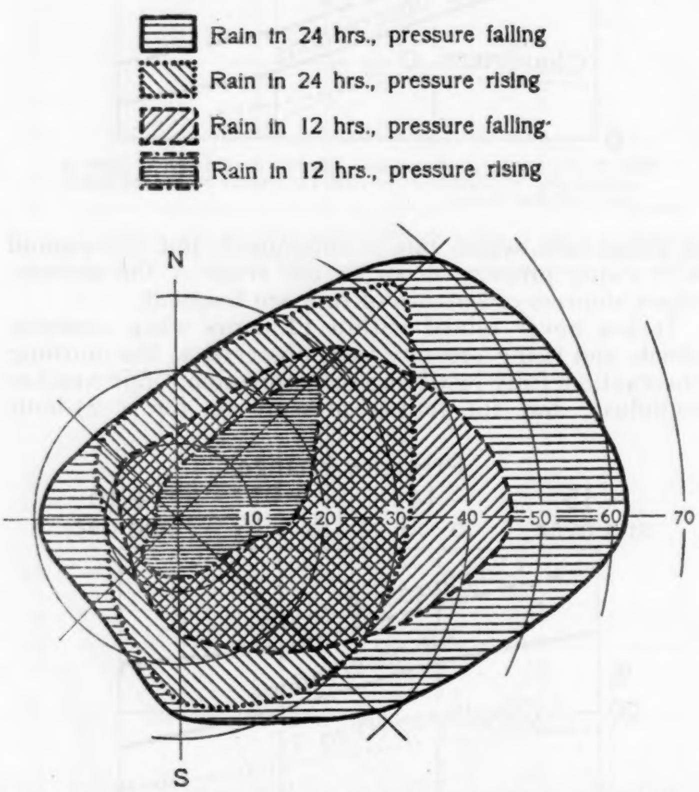


FIG. 9.—Percentage of observations followed by 0.01-inch or more of precipitation within 12 and 24 hours, as related to wind direction. Days with rain falling at observation omitted; 3,132 observations

The second set of curves of Figure 10, and the data in Table 2, on which they are based, yield a quite unexpected relation between wind velocity and rainfall, for which no adequate explanation is evident. For the greater part of their length the four curves are arranged in the order of the velocities represented, the probability of rain *decreasing* consistently with *increasing* velocity. Especially distinct is the increased probability following conditions of practical calm, winds of zero to 4 miles per hour. The general condition holds, though somewhat less consistently, when the data are classified by pressure change, as in Table 3.

In the relation of wind direction and cloudiness to rainfall, the spreading of the curves at northeast and east in Figure 11 indicates that in most cases of rain with these winds cloudiness has already developed at the morning observation to give additional indication. The curves showing the relation between pressure change and wind direction emphasize in fuller detail the fact already indicated in Figure 9 that with falling pressure the most frequent rain-bearing winds are from the east, and with rising pressure from the northeast. With a rise of 0.16 inch or more, this becomes very marked, northeast rising to 59 per cent, and east falling to 17 per cent, which is below southeast, south, and north. When it has been raining with northeast wind and rising barometer and

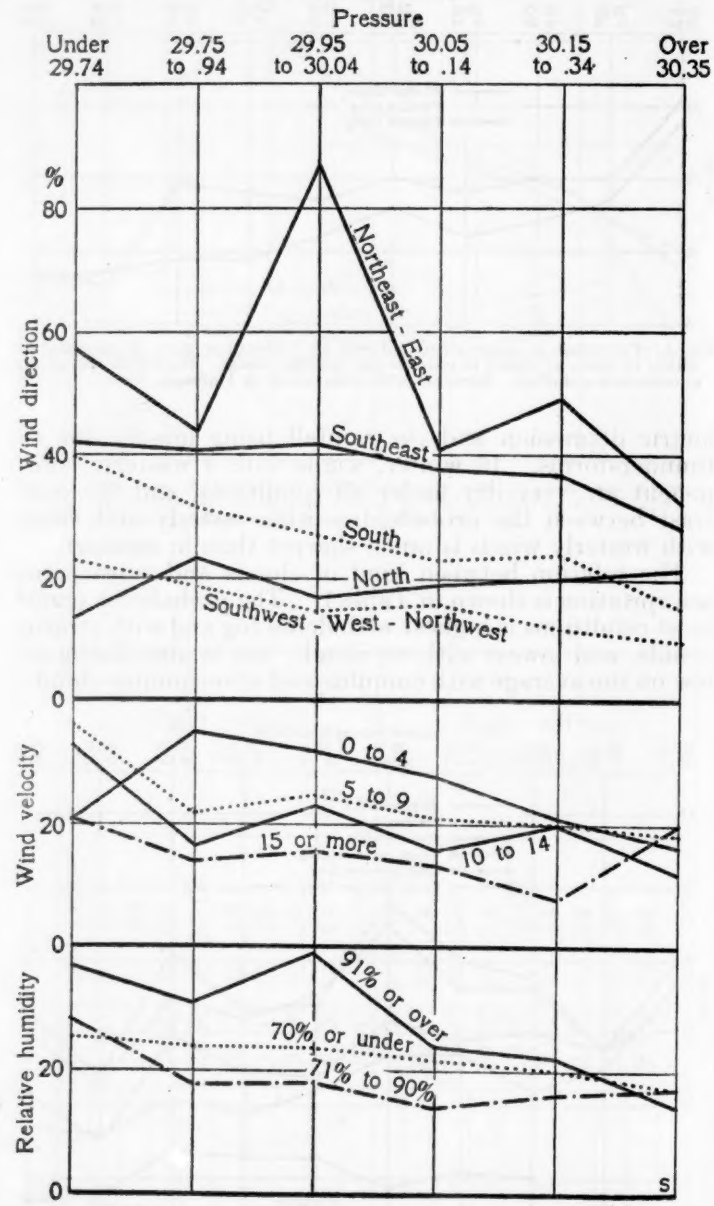


FIG. 10.—Rainfall percentages resulting from the simultaneous consideration of two meteorological elements. Amounts of 0.01-inch or more within 24 hours

the wind veers to the east, we can say with confidence that the rain is practically at an end.

Among other conclusions to be drawn from the tables but not shown graphically, may be mentioned: The probability is greatest in general with high positive temperature departures, but is greatest with negative departures when the pressure is very high. In Table 4 it is seen that high relative humidity furnishes an indication of rain only when combined with positive temperature departures or cloudy weather. With negative departures

[5] Rolf, Bruno, Probabilité et Pronostics des Pluies D'Été, Upsala, 1917.

it even seems more likely to rain with average or low humidities; with clear weather humidity is without significance as to coming rain. That pressure change, cloudiness, relative humidity, temperature change, and wind direction are not independent variables must be borne in mind, however. The closely interrelated character of the data with which we are dealing is made very evident by these tables and curves.

In the actual application to forecasting of such results as have been obtained in this discussion, Besson [6] has used a simple method which deserves to be more widely

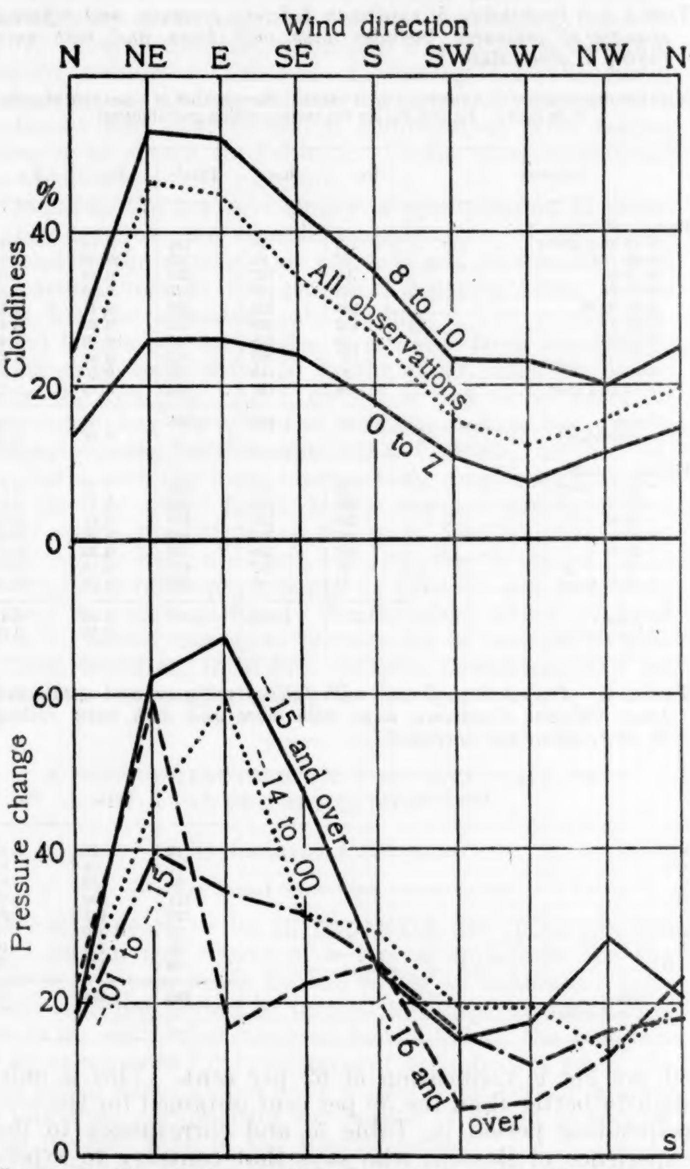


FIG 11.—Rainfall percentages resulting from the simultaneous consideration of two meteorological elements. Amounts of 0.01-inch or more within 24 hours

known and widely applied. He has used simple tables giving essentially the same facts as are given by the curves discussed in the beginning of this article, but has gone further by making actual forecasts from the data and computing the percentage of verification. Table 5 presents after the manner of Besson the data shown graphically in the "all observations" curves of Figures 1 and 2, and Table 6 a portion of the data used in Figure 9.

In order to consider the probability of rain as a function of two elements, Besson constructs tables of rectangles, and draws thereon probability isograms. The general method is illustrated in Figure 12, in which the probability of rain in 24 hours, including traces, is expressed as a function of pressure and pressure change. The values are smoothed by calculating the percentage

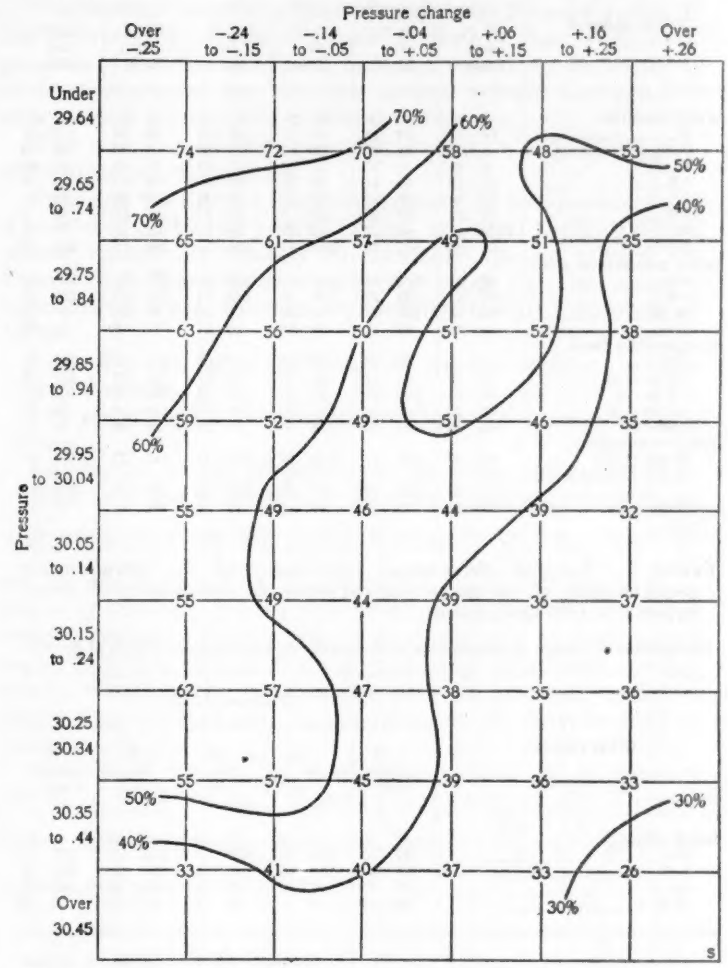


FIG. 12.—Rain probability as a function of pressure and pressure change (after Besson). The numbers entered on the figure are the mean percentages of rain within 24 hours, including traces, for the four adjoining squares. Data of 3,606 observations at Dubuque, Iowa

for the four squares at the center of which the percentage is entered. The results are fairly consistent, and a diagonal from the lower left-hand corner approximately represents the 50 per cent line. By forecasting rain for all cases represented here when the percentage is over

TABLE 1.—*Percentage of observations followed by 0. 01 inch or more of precipitation within 12 and 24 hours, as related to kind of clouds*

[Days with rain falling at observation omitted; 3,455 observations]

Pressure falling				Pressure rising			
12 hours		24 hours		12 hours		24 hours	
Clouds.	Per cent	Clouds	Per cent	Clouds	Per cent	Clouds	Per cent
Fog	30	Fog	45	A. cu	12	Fog	24
St	23	St	33	St	11	St	23
St. Cu	22	Ci. Cu	33	St. Cu	11	Ci	22
Ci. Cu	20	St. Cu	28	Ci	8	A. St	19
A. St	15	A. St	26	A. St	7	A. Cu	19
Ci. St	11	Ci. St	26	Ci. Cu	5	Ci. St	18
Cu	10	Cu	20	Fog	4	St. Cu	17
Ci	6	Ci	18	Ci. St	4	Cu	17
A. Cu	4	A. Cu	13	0	2	Ci. Cu	11
0	3	0	12	Cu	0	0	10

[6] Besson, Louis, Essai de prévision méthodique du de l'emps, Annales Observatoire Municipal (Montsouris), vol. 6, 1905; 473-496.

TABLE 2.—*Rainfall percentages resulting from the simultaneous consideration of two meteorological elements, based on 3,245 observations at Dubuque Iowa,*

[n=number of cases. p=percentage with rain of 0.01 inch or more within 24 hours]

Other element	Pressure: 29.74 and under		29.75 to 29.94		29.95 to 30.04		30.05 to 30.14		30.15 to 30.34		30.35 and over	
	n	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*
Wind direction:												
N	14	14	31	23	24	17	43	19	98	20	112	21
NE	8	75	16	50	12	92	15	40	34	50	50	30
E	4	25	4	25	11	82	17	41	27	48	26	35
SE	31	42	54	41	50	42	64	38	108	37	75	28
S	55	40	109	32	82	27	91	23	137	24	93	15
SW	32	34	70	20	40	5	47	15	81	17	50	4
W	29	17	66	17	53	17	46	17	102	11	75	5
NW	64	20	157	19	115	17	126	16	260	11	224	13
Wind velocity (m.p.h.):												
0-4	66	21	192	35	152	32	225	28	435	21	385	16
5-9	92	37	193	22	158	25	162	21	315	20	270	18
10-14	60	33	103	17	70	23	62	16	95	20	65	12
15+	24	21	37	14	19	16	14	14	37	8	15	20
Temperature Dept.:												
−11+	8	—	29	21	28	18	64	25	234	19	381	19
−4 to −10	16	19	45	11	55	20	93	17	184	20	162	18
−3 to +3	30	23	100	25	87	29	101	22	201	19	103	11
+4 to +10	56	23	163	20	111	25	104	17	138	18	58	12
+10+	132	35	187	34	118	33	86	29	94	30	19	11
Relative humidity:												
91 per cent+	67	37	131	31	105	39	107	24	185	22	187	14
71 per cent to 90 per cent	141	26	320	24	250	24	297	22	572	20	470	17
70 per cent −	34	29	73	18	44	18	44	14	94	16	66	17

TABLE 3.—*Rainfall percentages resulting from the simultaneous consideration of two meteorological elements, based on 3,245 observations at Dubuque, Iowa*

[n=number of cases. p=percentage with rain of 0.01 inch or more within 24 hours]

Other element	Pressure change: −.15 and over		−.14 to −.05		−.04 to +.05		+.06 to +.15		+.16 and over	
Wind velocity:	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*
0-4	147	36	279	26	470	24	352	19	207	15
5-9	228	27	216	28	248	21	231	19	267	16
10-14	107	34	54	17	63	26	88	9	143	15
15 & +	26	19	8	—	21	19	32	12	59	10

	−.15 and over		−.14 to .00		+.01 to +.15		+.16 and over	
Wind direction:	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*
N	10	20	49	20	163	18	100	23
NE	16	62	38	45	59	39	22	59
E	12	67	27	59	44	34	6	—
SE	128	47	162	31	83	31	9	—
S	174	24	269	29	116	25	8	—
SW	82	15	123	19	82	16	33	6
W	36	17	88	19	148	12	99	7
NW	39	28	135	13	390	16	382	13
Cloudiness:								
0-7	193	18	404	17	606	13	431	10
8-10	304	38	487	33	479	28	228	26

TABLE 4.—*Rainfall percentages resulting from the simultaneous consideration of two meteorological elements, based on 3,245 observations at Dubuque, Iowa*

[n=number of cases. p=percentage with rain of 0.01 inch or more within 24 hours]

Cloudiness	Wind direction: N		NE		E		SE		S		SW		W		NW	
	n	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*
0-7	157	14	34	26	23	46	132	24	282	18	193	11	253	8	560	11
8-10	165	25	101	53	66	52	250	43	285	35	127	23	118	23	386	20

Relative humidity	Temperature departure: −11 and over		−4 to −10		−3 to +3		+4 to +10		+11 and over	
	n	*p*	*n*	*p*	*n*	*p*	*n*	*p*	*n*	*p*
91 per cent and over	202	17	121	18	122	22	141	24	196	42
71-90 per cent	468	21	381	17	453	21	395	19	353	29
70 per cent and under	74	16	53	28	46	11	94	15	87	19

TABLE 4.—*Rainfall percentages resulting from the simultaneous consideration of two meteorological elements, based on 3,245 observations at Dubuque, Iowa*—Continued

Relative humidity	Cloudiness: 0-3		4-7		8-10	
	n	*p*	*n*	*p*	*n*	*p*
91 per cent and over	283	13	65	25	432	34
71-90 per cent	870	11	269	21	911	31
70 per cent and under	165	12	53	11	137	28

TABLE 5.—*Probability of rain with different pressures and different changes of pressure; includes days with trace and with rain falling at observation*

[R_{12}=number of times rain recorded in 12 hours. R_{24}=number of times rain recorded in 24 hours. P_{12} and P_{24} are the corresponding probabilities]

Pressure	R_{12}	R_{24}	Total	P_{12}	P_{24}
Pressure change:					
29.64 and under	112	130	161	0.70	0.81
29.65-74	86	94	163	0.53	0.58
29.75-84	108	127	239	0.45	0.53
29.85-94	143	197	370	0.39	0.53
29.95-30.04	160	203	436	0.37	0.47
30.05-14	152	208	501	0.30	0.42
30.15-24	154	218	517	0.30	0.42
30.25-34	137	192	446	0.31	0.43
30.35-44	81	119	321	0.25	0.37
30.45 and over	84	147	452	0.19	0.33
Total	1,217	1,635	3,606	.34	0.45
Verification				0.68	0.59
Pressure change:					
−.25 or more	150	167	260	0.58	0.64
−.24 to −.15	205	236	389	0.53	0.61
−.14 to −.05	259	326	639	0.41	0.51
−.04 to +.05	281	383	862	0.33	0.44
+.06 to +.15	197	295	753	0.26	0.39
+.16 to +.25	81	147	417	0.19	0.35
+.26 or more	44	81	286	0.15	0.28
Total	1,217	1,635	3,606	0.34	0.45
Verification				0.65	0.59

TABLE 6.—*Probability of rain with falling pressure and with wind from different directions; days with trace and with rain falling at observation not included*

Direction	R_{24}	Total	P_{24}
N	12	59	0.20
NE	27	54	.50
E	24	39	.62
SE	111	290	.38
S	120	443	.27
SW	35	205	.17
W	23	124	.19
NW	28	174	.16
Total	380	1,388	.27
Verification			.73

50, we get a verification of 62 per cent. This is only slightly better than the 59 per cent obtained for the corresponding period in Table 5, and corresponds to the experience of Besson, who says that contrary to expectations the two-element combinations do not offer much superiority over the results with one element. However, he constructs eight such figures, giving eight combinations of two elements each, and according as the arithmetical mean of the eight probabilities shown is above or below 0.50, forecasts rain or no rain, and obtains a verification of 73 per cent for 943 cases.

Besson forecasts rain when the tables show a probability above 0.50, and no rain when below 0.50. In Table 5 only when the barometer is below 29.75 is the probability of rain within 12 hours above 0.50. Given only this element, then, he would forecast rain whenever the barometer is below 29.75, and fair weather under all other conditions. To get the percentage of verification

which such forecasts yield, add the number of cases of rain when the pressure is below 29.75 to the number of cases it did not rain when the pressure is above this figure, and divide by the total number of observations.

In this case we get $198+2{,}263 \div 3{,}606=0.68$. By this simple rule the forecasts are correct 68 per cent of the time for rain in 12 hours, and by a similar calculation 59 per cent for rain in 24 hours, forecasting rain in the latter case when the pressure is below 29.95 inches. Besson uses this method for the observations at Montsouris with six elements, pressure, direction and velocity of wind, temperature, cloudiness, and pressure change, and obtains percentages of verification ranging from 58 to 67. Traces and days when rain was falling at observation are included in Table 5. Excluding these the winter probability at Dubuque never rises to 0.50 except with northeast and east winds in combination with falling pressure as shown in Table 6. Under these conditions the verification is 73 per cent.

Owing to the low probability of precipitation of measurable amount, the complete application of the above method to the data of this paper is not practicable, and we must revert to the graphical representation of the facts for the essential relationships. The results obtained by Besson and those obtainable from the graphs fall short of those obtained by the experienced forecaster using the synoptic chart, and it is not to be assumed that conditions observed at a single station can give a complete basis for formulating a forecast, as, indeed, the chart and the local observations combined can not do. On the other hand, many weather proverbs and many of the predictions of mariners, farmers, and other outdoor men have a certain validity, due to the fact that locally observable phenomena do precede and announce coming weather changes. A statistical study of local data, by classifying these phenomena in relation to subsequent weather, furnishes valuable supplementary information and suggestion to the forecaster.

A NEW PRINCIPLE IN THE ANALYSIS OF PERIODICITIES

By CHARLES F. MARVIN

[Weather Bureau, Washington, March 24, 1924]

What appears to be an important new principle has come out in the course of a recent application of the Fourier analyses made by the writer to evaluate a supposed sun-spot period in terrestrial temperatures. This has to do with what happens in the use of the analyses or other schemes for investigating periodicities when the data under examination have within them certain known or unknown periodicities the length of which is shorter than the last term of the Fourier series.

The demonstration which follows is built up around the Fourier series merely as a convenience contributing clearness and comprehensiveness of presentation. The principle itself is concerned only with the body of data investigated and the significance of certain features thereof, and the Fourier theorem is nothing whatever but a symbolism employed to conveniently exhibit the facts.

The present consideration presupposes, of course, that the whole number of phase values of data available is finite and limited, and consequently a finite and limited, although possibly a large number of terms of the series will nevertheless completely reproduce the original observations.

The point brought out in this note may be old and well known, but the writer has not as yet seen it discussed,[1] and experience indicates that it is neither avoided nor adequately discounted in many serious studies of alleged periodicities in meteorological data.

The principle may be stated in the following form:

The several terms of a limited and finite Fourier series do not necessarily represent single or unique harmonic components of the data analyzed, but each term may theoretically at least represent two or even several wholly independent components with widely different periods.

The analysis of this question does not appear to present material difficulties.

Suppose we have a long record, say of temperature for a period of 50 to 100 years or more, and that the individual phase values are weekly or monthly means. Now we know that this entire series of values can be exactly reproduced by a Fourier series with a finite number of terms.

Let K = the large number of phase values in the original record.

Let p = the relatively small time interval between phase values.

Let l = the length of period in the same time units.

Now we learn from the Fourier theorem that there will be a term in the series whenever the fraction $\frac{Kp}{l}$ equals an integer 1, 2, 3, etc.; that is, all the features of the original long record will be expressed as if they were equivalent to a long series of periodicities of designated wave lengths. It is of no significance whatever in this study whether the component periods are real or false. Some may be real and others false, or all may be real or false.

Assuming simply for convenience that K is exactly divisible by 4 we find that the last term in the Fourier series corresponds to the wave length $\frac{Kp}{l=2p}=\frac{K}{2}$ and the whole series appears thus:

$$\frac{Kp}{l}=1,\ 2,\ 3,\ 4,\ 5,\ .\ .\ .\ .\ .\ .\ .\ .\ .\ \frac{K}{2} \quad (1)$$

Now we are never able to make practical use of the theory when p is a relatively small interval of time and K is a very large number running into the hundreds or thousands, as assumed above. In practice we content ourselves with making p a relatively large number, P, and K a correspondingly smaller number, k so that the product $kP=Kp$.

It is perfectly obvious that these simplifying assumptions can not in the slightest way affect any of the characteristic features of the original data or the real existence of all of the terms of the series (1) as representing the original data.

We assume in the foregoing that the k phase values at large intervals P are actual observations at the times in question, and we shall continue this assumption for a moment. In actual problems of this kind it is a customary although a faulty practice to assemble a greater or less number of observations contiguous to the desired phase date into a representative mean *as of that date.*

[1] While this note was in process of publication the March issue of the Proceedings of the Royal Society, series A, vol. 105, No. A 731, was received at our library, and the article, A Difference Periodogram, by C. E. P. Brooks, p. 346, brought to my attention. While Dr. Brooks does not discuss in its generality the principle presented by the writer, nevertheless he makes use of it to evaluate short periodicities in the disguise of periods of much greater length.

The effect of the reduction in the number of phase values is simply to divide the original complete series represented by (1) into a series of groups entirely analogous to spectra of the first, second, and higher orders, resulting in the phenomena of diffraction. This is indicated by writing the original series in the following form:

PERIODICITIES OF THE

$$\frac{Kp}{l}=\frac{kP}{l}=\overbrace{1,2,3,..\frac{k}{2}}^{\text{First order.}};\ \overbrace{\frac{k}{2}+1,2,3,\ldots.k}^{\text{Second order.}};$$

$$\overbrace{k+1,2,3,\ldots\frac{3k}{2.}\cdot\cdot\frac{K}{2}}^{\text{Third and higher orders.}} \tag{2}$$

It is not difficult to show that the 1st and 2nd, including other higher *even* orders stand in the relation of rights and lefts to each other, or they are *complementary* in that the wave lengths run from long to short in the 1st and odd orders, whereas they begin short and run to long waves over the sequence of terms as they occur in the periodicities of the *even* orders. In other words, the actually shorter and shorter periods of the 2nd order are, as it were, reflexed back upon terms of the 1st order series, just as if the actual wave lengths were all longer and longer than the real waves of the 2nd and all other higher *even* orders. Each wave of an even order differs by 180° in phase from its complementary wave of the odd order. Again, comparing all the odd orders with each other they may be called companion orders in that the sequence of terms in both cases begin with long and end with short periodicities.

The very discomfiting thing about this whole matter is that all the higher order of periodicities exhibit themselves in disguise just as if they were *bona fide* terms of the first order, which are the only terms that can be evaluated from the k phase values adopted.

The application of the new principle to investigations of periodicities is simply this: All periodicities in the original data of shorter wave length than the shortest one it is expected will be evaluated by the method of analysis employed tend to remain and reproduce themselves, not, of course, as periodicities of very short wave length, but instead as false or disguised periods of long wave lengths. This is especially the case with short periods which are commensurate with the fundamental interval covered by the observations. This result is both helpful and harmful, helpful because the operation of the principle enables one to evaluate with all necessary accuracy the constants of a *known* short period as a long period parading in disguise in the 1st order periodicities. For example, in the analysis of 100 years of monthly temperature values (1,200 in all) the *annual period* was transformed by this new principle into the fourth and eighth harmonics of lengths of 25 and 12.5 years, respectively. While the use of 5 months' means necessarily operated to reduce the amplitudes of the 6 and 12 months' periods appreciably, nevertheless the phase angles were evaluated with great exactness. Both of these periodicities really belong to the fifth order.

The harmful results come about because we can not know in all cases whether the several components of the first order periodicities are *bona fide* relatively long waves or whether they are short-period waves drawn out or disguised into false long waves.

The force of these assertions may appear more clearly if illustrated by a very simple, concrete example, with diagram and a tabulation showing how the terms of the high-order periodicities dispose themselves over the group of terms constituting the first order of periodicities, which are the only ones which can be evaluated.

Suppose we have 48 fundamental phase values of some complex periodic variable for analysis and resolution. Suppose, also, that with the idea of lessening the labor or otherwise simplifying the work, we decide to use only 12-phase values—that is, we adopt a phase value for every fourth fundamental value. Six harmonic terms of the Fourier series will, therefore, completely reproduce the 12-phase values. However, each one of these six components is a possible composite of four entirely independent periods of widely different wave lengths. The heavy dots in Figure 1 represent 12 possible phase values out of the total 48 fundamental observations. These dots are common both to a long wave with a period of 48 fundamental time units, and to a short period of only $3\frac{9}{13}$ time units. These same dots are common also to two other short periods, not drawn, of $4\frac{5}{11}$ and $2\frac{2}{23}$ time units, all of which, with others, could be present in the original 48 fundamental observations.

The lower portion of Figure 1 shows how the 24 possible harmonic components group themselves when one attempts to simplify the analysis by reducing the 48-phase values to 12, as assumed above, resulting in six harmonic components of four orders of periodicities, namely, first, second, third, and fourth. If the reader will imagine the table cut out and wound into a cylinder, it is easy to see how the projections and indentations at the opposite ends interlock and form a continuous and symmetrical arrangement.

It is hoped the foregoing makes very clear how difficult it is to get at the absolute truth concerning complex periodicities.

However, many may be tempted to say yes, but no one would be foolish enough to base an analysis on 12 isolated phase values such as shown by the dots in Figure 1, but would use large group means instead. The answer is, *the isolated values are the only ones capable in the long run of disclosing the truth.* The group means tend to efface amplitude and displace phase characteristics. Large group means and more or less powerful smoothing formula tend to obscure, not reveal, the real but unknown periodic characteristics of data and must be used and resorted to with great caution, discretion, and understanding.

Of course, large group means are highly useful and trustworthy in dealing with great outstanding, well-understood periodicities, such as the 11-year sun-spot period, the annual and diurnal periods of temperature, etc. But our real quandary and search for periodicities are concerned with uncertain and obscure features with very small amplitude.

The foregoing consideration clearly bring us face-to-face with a serious dilemma in the investigation of periodicities. How is it to be met? Obviously, the reduced number of k phase values adopted for final analysis must be entirely free of any possible unknown short periodicities or more or less systematic fluctuation or residuals of such features. Is this prerequisite satisfied by the common practice of taking certain group means or by the use of certain favorite smoothing formulae?

The answer to both these questions is emphatically *no.* A 12-months' mean temperature, for example, is of course free of any possible annual period or exact submultiples thereof, but possible periodic features of 5 months, 7 months, and many other longer wave features are not thus eliminated, and we simply delude ourselves

and invite erroneous conclusions and inferences to proceed upon any assumption that such features are eliminated.

In the case of the possible periodicities of long wave length, the only rational course preeminently requires a preliminary investigation to disclose and evaluate all the possible short periodicities or demonstrate that they are absent. If present these short periodicities must be eliminated and segregated before a sane study of the long periodicities is possible. It is not a question whether the short periods are real or false. The preliminary analysis must show what features are present in the data which have the semblance of periodicity. Their existence and presence in the original body of data makes it impossible to draw safe conclusions concerning any long periods, and we must not overlook the fact that so long as the final amplitude of the hidden and obscure periods claimed by some to exist is only of the same order as, or even less than, the size of the residuals which remain uneliminated by the faulty methods of taking group means, thereof must appear in the adjusted data disguised as false long periods. Such disguised long periods are bound to be brought out subsequently if any sort of adequate analysis of periodicities is employed, whether it be the Fourier analysis or any other scheme. At any rate, the writer believes attention has been called to an interesting new principle in periodicities that seems to uncover a kind of pitfall or snare to trap the overconfident claimant of periodicities.

Accidental features and fortuitous fluctuations of data are of great importance in the present connection. These and many other details are fully recognized by the writer but can not be discussed in this brief note.

BASIC PRINCIPLES GOVERNING THE USE OF THE PERIODICITY TABULATION

It seems appropriate to add these brief notes in order to fairly round out and complete this article dealing with the investigation of periodicities.

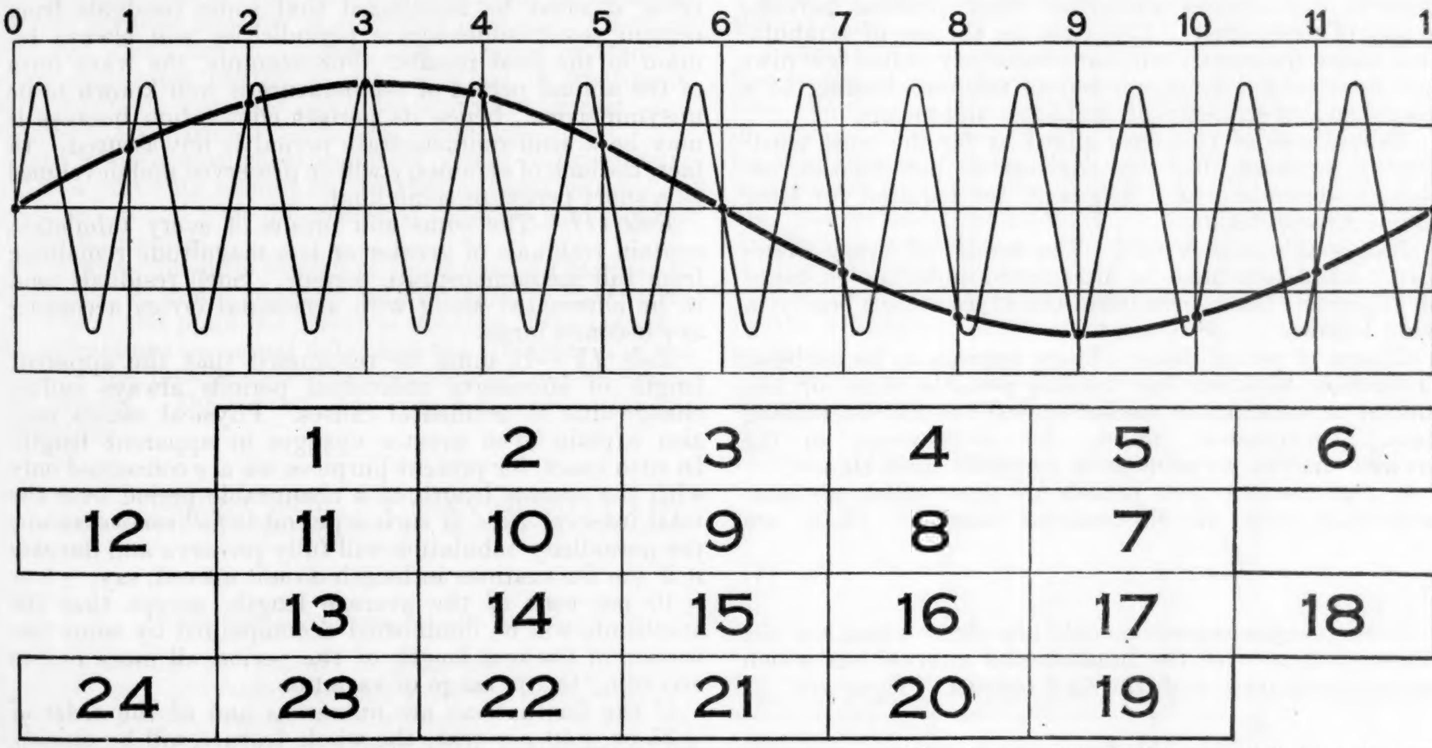


FIG. 1.—Representing (above) how 12 phase values out of 48 possible independent observations can represent either a long wave of the first order of periodicities or a short wave of the third order of periodicities, and (below) a tabulation showing the distribution of 4 orders of periodicities of 6 terms each which arise when 48 observed values are reduced by combination or otherwise to 12 phase values.

of smoothing, etc., while these two magnitudes are of the same order, the proof of periodicities is unacceptable or inadequate unless the causes of error herein discussed are avoided.

It seems necessary to repeat here that it is of no consequence that the present demonstration of a new principle in periodicities is built up around the Fourier analysis. The latter is used simply as a convenient symbolism to facilitate a clear and comprehensive presentation. The principle itself really has nothing to do with the Fourier theorem, but declares what happens in any kind of analysis of assumed periodicities when data are arbitrarily smoothed and combined into larger or smaller group means with the declared object of *eliminating* recognized troublesome short periods and irregularities. It can not be claimed that a particular group mean eliminates all possible short periods at the same time. Residuals

It is well known the familiar device here called the periodicity tabulation comprises r rows of K columns of homogeneous values of data at unit intervals of time and supposed to possess periodic characteristics. A tabulation may be indicated as follows:

$$\begin{array}{lcccc}
 & a_1 & a_2 & a_3 \ldots\ldots\ldots\ldots & a_k \\
 & b_1 & b_2 & b_3 \ldots\ldots\ldots\ldots & b_k \\
 & * & * & * \quad * \quad * \quad * & \\
 & r_1 & r_2 & r_3 \ldots\ldots\ldots\ldots & r_k \\
\hline
\text{Sums} \ldots\ldots\ldots & S_1 & S_2 & S_3 \ldots\ldots\ldots\ldots & S_k \\
\text{Means} \ldots\ldots\ldots & m_1 & m_2 & m_3 \ldots\ldots\ldots\ldots & m_k
\end{array}$$

The unit of time may for convenience be assumed to be the time interval between columns, as days, months, years, etc. We may then designate the K time units embraced by a single row as the *fundamental interval*.

Similarly, the quantity Kr in time units may be designated the *total interval*. For example, a 4-row 27-column tabulation of *monthly* means would have a fundamental interval of 27 months and a total interval of $4 \times 27 = 108$ months.

Elemental tabulations.—Almost every one thinks of the scheme called a periodicity tabulation as a device to eliminate various features of data, except one supposed elemental period which the tabulation will segregate from all other periodic, nonperiodic, irregularly recurrent and accidental values, and thus evaluate the periodic term alone and by itself. This idea works out beautifully in the case of such outstanding periods as the annual and diurnal periods of pressure, and temperature and annual periods of precipitation and other elements of meteorological data.

Complex tabulations.—However, the tabulation has a vastly wider utility than this. It is just as proper to use it in a manner that will *eliminate* some one particular period like the diurnal or the annual periodicity, and *preserve and develop* numerous other possible periods, if any of them exist. This calls for the use of a tabulation which frequently will have relatively only a few rows but relatively a large number of columns leading to a very complex sequence of final sums and means.

Tabulations of this kind afford by far the most trustworthy evidence for the analysis of periodicities, although experience and judgment are required for their sound interpretation.

Interpretation of results.—The results of every periodicity tabulation must be interpreted under the guidance of important basic principles which are stated briefly in what follows.

Classes of periodicities.—There appears to be no basic distinction between the various possible more or less hidden periodicities in meteorological and like fluctuating data. Nevertheless, purely for convenience in the present analysis we propose to recognize three classes:

1. *Full commensurate periods* are those which are commensurate with the *fundamental interval*.[1] These are

$$\frac{K}{l} = 1, 2, 3 \ldots\ldots\ldots\ldots \frac{K}{2} \qquad (1)$$

2. *Semicommensurate periods* are those which are *not* commensurate with the fundamental interval but which *are* commensurate with the *total interval*. These are

$$\frac{Kr}{l} = 1, 2, 3, 4 \ldots\ldots\ldots\ldots \frac{Kr}{2} \qquad (2)$$

The last terms in (1) and (2) are

$$\frac{K-1}{2} \text{ and } \frac{Kr-1}{2},$$

when K and Kr are odd.

It will be noticed by equation (1) that the possible number of full commensurate periods is fixed and unchangeable as long as the number of the columns K remains constant. In contrast to this, the possible *semicommensurate* periods steadily change and increase as the number of rows r increases.

3. Finally, *full incommensurate* periods are those which can not satisfy the conditions in either class (1) or (2). some of these, however, may, fall into class (2) when a change is made in r.

[1] Periods which are within a few per cent of *full commensurate* will, of course, quite fully emerge from a tabulation, especially if the number of rows is relatively small, or, better stated, if the excess or deficit of commensurability as a percentage *times the number of rows* is less than about 25 per cent. If sufficient data are available to permit of 3 or 4 consecutive groups of tabulations, the true length of the period can be approximated from the amount by which the phase of the wave is found to advance or retrograde.

Rule I.—Every full commensurate periodicity is preserved and developed in all its characteristics by any tabulation, and at the same time the accidental errors and irregular and fortuitous fluctuations, including nonperiodic features present in all data are gradually eliminated, according as the number of rows, r, is increased. There are certain exceptions or reservations arising under this rule which will be mentioned later. (See Rule IV.)

Rule II.—Every semicommensurate periodicity will be *completely eliminated* by a tabulation, *provided* its wave form is symmetrical and the number of rows is sufficient to fairly exclude large accidental features. Even though the wave form of a given period may tend to become symmetrical in the long run, this prerequisite to complete elimination is not satisfied by individual waves, and since certain reasons may sometimes compel the investigator to employ only a limited number of rows, it must be recognized that some residuals from certain semicommensurate periodicities will always remain in the final results. For example, the wave form of the annual period of temperature is well known to be unsymmetrical, hence its perfect elimination because it may be a semicommensurate period is not assured. In fact, the lack of symmetry will be preserved and developed as a short period of some kind.

Rule III.—The sums and means of every tabulation contain residuals of greater or less magnitude remaining from full incommensurate periods. Such residuals tend to be eliminated along with accidental errors according as r becomes large.

Rule IV.—It must be recognized that the apparent length of successive individual periods always suffers change due to accidental causes. Physical causes may also explain even greater changes in apparent length. In such cases, for present purposes we are concerned only with the *average* length of a changeable period over the total interval Kr. If such a period is *full commensurate*, the periodicity tabulation will fully preserve and develop it if the fluctuations in length do not exceed, say, ± 5 or ± 10 per cent of the average length, except that the amplitude will be diminished accompanied by some distortion of the real length of the period all more or less according to the range of variation.

If the fluctuations are numerous and of the order of ± 25 or ± 50 per cent, the whole feature will be quickly eliminated or reduced to small residuals which are indistinguishable from many other residuals and accidental errors always present and due to other causes.

If its average length places one of these changeable periods in class (2) or (3) its fluctuation in length, even when small, combines with the consequences of incommensurability to quickly and effectually eliminate it from the results of a tabulation.

While the author recognizes the full possibilities under the foregoing assumptions, nevertheless, based on any evidence thus far adduced, he is compelled to consider it a misuse of terminology to apply the term "period" or "cycle" to erratic recurrent features which exhibit rapid and frequent changes in length of 50 or 100 per cent, and he must disclaim any belief that such features are due to real physical causes rather than being the product of spurious or accidental recurrences, at least until some reasonable physical explanation thereof is convincingly presented.

Of course, if the law controlling the changes of length becomes known quantitatively it will always be easy to adjust the tabulation to meet such a prerequisite.

Rule V.—As immediate consequences of the foregoing rules the results of any periodicity tabulation will be a composite aggregate of possibly several real commensurate periods, probably of small amplitude, upon which will be superposed numerous accidental errors and many uneliminated residuals, greatly obscuring the actual facts.

In the examination of the results it must constantly be recognized that sequences of wholly fortuitous numbers will always exhibit periodic features, and these, as well as all real commensurate periods, can be evaluated by the Fourier analysis or other devices. Nevertheless, only those features can be claimed as real which emerge and persist and endure in a more or less consistent fashion, regardless of some particular method of derivation. The results must be derived in as many legitimate and different ways as possible. Only those features which consistently survive and emerge from every analysis can be regarded as real periodic features in any body of data. All those features which vanish, change, and reappear incident to every legitimate change of data, method of treatment, etc., must be regarded as quite spurious, unreal, and largely the vagaries of fortuitous conditions.

The whole atmosphere can not, of course, be expected to act as a unit with respect to periodicities, and we must be prepared to find wide differences at different times and in different localities.

If it were not quite foreign to the scope and purpose of this note, it would be most interesting and instructive to show at this point the practical working of the periodicity tabulations on actual data, and the application of the rules in the interpretation of complicated results which are secured. These must, however, be reserved for another time.

FITTING STRAIGHT LINES TO DATA GREATLY SIMPLIFIED WITH APPLICATIONS TO SUN-SPOT EPOCHS

By CHARLES F. MARVIN

[Weather Bureau, Washington, March 24, 1924]

Many studies of the data of meteorology, economics, business, etc., are facilitated and definite results may be expressed by the evaluation of a straight line of best fit to the statistics involved. This is often accomplished in an approximate way by graphical methods, but in a great many cases a far more certain and accurate result can be secured by a very simple arithmetical calculation following rigorously the principle of least squares. Moreover, the computation really entails much less time and effort than that required to produce the less accurate scale drawing of the necessary chart.

The cases in which this simple method can be used arise whenever the data correspond to exactly equal and uniform intervals of time, like days, weeks, months, seasons, etc. In still other cases the observed values correspond to a series of abstract integers like 0, 1, 2, 3, etc., which represent recurrences of certain features, such, for example, as consecutive observations of the epochs or dates of the minima, or maxima of the sun-spot period. Finally, even when the original layout of the statistics does not satisfy the above simplifying condition it is often possible to make some simple adjustments of the data so that the simplifying condition is satisfied. It seems from the foregoing that there are a large number of problems in which the simple computations can be employed, and every student of statistics should be perfectly familiar with it.

The problem is to compute the best values (as defined by least squares) of the constants a and b in the general equation of the straight line,

$$y = a + bx$$

where y represents any series of observations corresponding to integral values of $x = 0, 1, 2, 3,$ etc.

In order to accomplish two objects in this same note, I will ask the reader to turn his thoughts for a moment to Newcomb's method [1] of evaluating the normal epochs of sun-spot phenomena and the normal length of the period. His normal value of the sun-spot cycle 11.13 years is widely quoted and universally accepted as probably the best evaluation of this puzzling solar feature. His method must, therefore, be, as it is, a very sound one, nevertheless it seems to be little understood and almost never used, either in the analysis of modern sun-spot data not available to Newcomb or in a hundred other problems of periodicities in other statistical data.

Newcomb's method is simply that of fitting a straight line to the observations which fix the dates of the maxima, the minima, the mid-phase values rising or falling, or any other chosen characteristic of data that may be available, and since the consecutive observed values correspond to successive abstract numbers 0, 1, 2, 3, etc., representing recurrences of the same thing, the simplifying condition of the arithmetical computation is satisfied at the outset.

Both objects of this note, therefore, are accomplished by the calculation of the sun-spot data since, say 1820, to date.

Observations.—We shall use the dates given by Wolfer for simply the minima of sunspots since 1820.

TABLE 1.—*Dates of epochs of minima of sun spots by Wolfer, 1820 to 1924*

x	y	c	x	y	c
0	1,823.3	+3.3	5	1,878.9	+3.9
1	1,833.9	+2.9	6	1,889.6	+3.6
2	1,843.5	+1.5	7	1,901.7	+4.7
3	1,856.0	+3.0	8	1,913.6	+5.6
4	1,867.2	+3.2	[1] 9	1,923.9	+4.9

[1] The epoch of the present sun-spot minimum has not as yet been established accurately, but it will probably differ very little from the date indicated.

Almost every student contents himself with the faulty method of deducing the average length of the period by subtracting the first date from the last one and dividing the difference by 9, viz, $\frac{100.6}{9} = 11.18$ years. This not only presupposes that the first and last dates are exact ones, but it wholly ignores the irregular intermediate dates, and any attempted adjustment of the intermediate epochs to a normal series assigns all the irregularities to the intermediate epochs, while the first and last stand 100 per cent perfect. This is clearly wrong, because we must presuppose that each of the dates is affected by some error or irregularity and determine the amount thereof fairly by the method of analysis. This is what Newcomb's method does.

GRAPHICAL SOLUTION

Procedure.—Lay off on the Y axis of a coordinate diagram a scale of dates beginning preferably a little

[1] Astrophysical Journal, vol. 13, 1901, p. 1.

before the date of the first observed epoch of minimum to be analyzed. Lay off points on this scale locating all the observed minima.

Transfer each of these points to consecutive ordinates at uniform intervals corresponding to x values 0, 1, 2, 3, etc. (See fig. 1.) Such points in general will fall in a diagonal, nearly straight line. Fit a straight line to the points as well as possible, either by eye or by analytical methods, and the problem is solved.

Results.—The slope of the line gives the normal length of the period. This value is best found by noting on the vertical scale two intersections of the line with two widely separated ordinates. The slope is the ratio of the two sets of differences, thus:

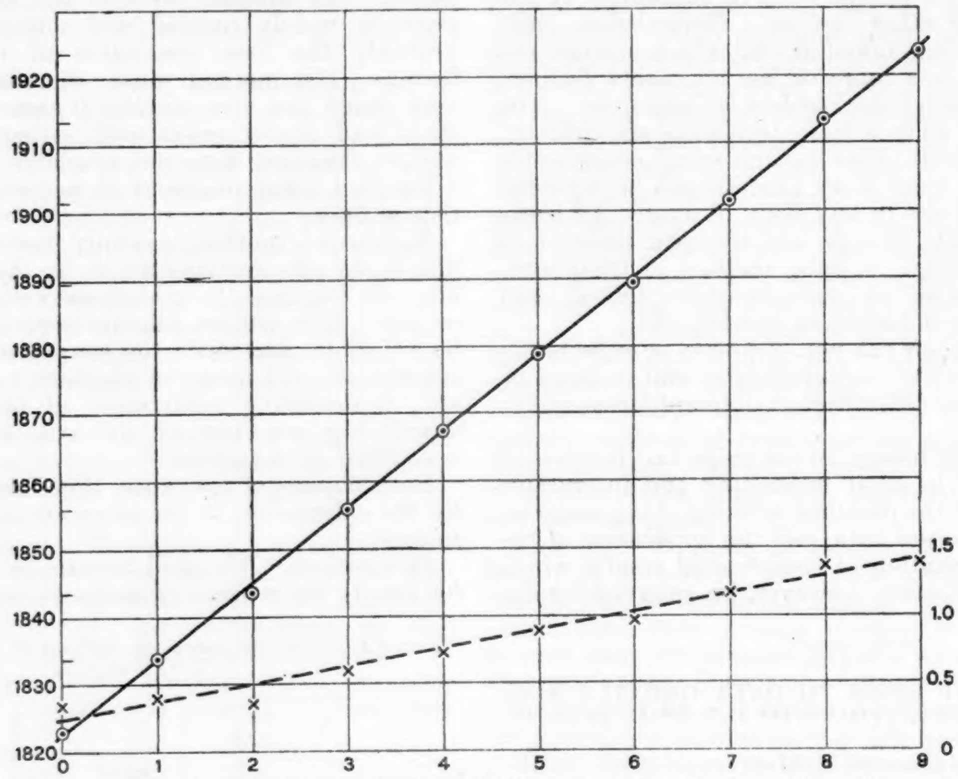


FIG. 1.—Representing the graphical solution of fitting straight lines to observations of epochs of minimum of sun spots, according to Newcomb's method

Intersection at ordinate 9 = 1924.0
Intersection at ordinate 0 = 1822.2
Differences............ 9   101.8

$$\text{Average period } \frac{101.8}{9} = 11.31 \text{ years.}$$

The several intersections of the line with the ordinates 0, 1, 2, 3, etc., fix the normal or adjusted dates for the corresponding minimum epochs.

Greater accuracy is attained in the graphical solution if the vertical scale is exaggerated. Assume a uniform 10 or 11 year interval and plot on an enlarged vertical scale the excess of the observed over the assumed regular intervals. The points located by the crosses in the lower part of the diagram (scale at right) show the excesses over the uniform scale 1820, 1830, 1840, etc.

ARITHMETICAL METHOD

We are to find the best values of a and b in the equation of the straight line

$$y = 1820 + a + bx$$

Simply to avoid large numbers we assume $b = 11.0 + b'$ and our working equation now becomes

$$a + b'x = (y - 1820 + 11.x) = c$$

The quantity c is now a small number for each observation instead of the awkward large number representing the dates of the several minima. Its values are given in Table I.

Procedure.—Write down the observations (c) in two columns (I, II) and form the differences, $d = (\text{II}-\text{I})$ as indicated. Multiply these by certain weights, g, in this case 9, 7, 5, 3, and 1. Find the sum of all the c's = 36.6, also of the products $gd = 51.8$

TABLE 2.—*Calculation of b' and a*

[$n = 10$. N (see Table 4) = 165. Weight = $n-1$, $n-3$, $n-5$, etc.]

	Observations c		Difference, II–I d	Weights g $n-1$, $n-3$, ...	Products gd
	I down	II up			
	3.3	4.9	+1.6	9	14.4
	2.9	5.6	+2.7	7	18.9
	1.5	4.7	+3.2	5	16.0
	3.0	3.6	+0.6	3	1.8
	3.2	3.9	+0.7	1	0.7
Sums	13.9	{22.7 13.9			
Total	$\Sigma c = 36.6$				51.8

$$b' = \frac{51.8}{N = 165} = 0.314$$

Hence $b = 11.314$ which is the best normal length of the sunspot period between 1820 and 1924.

$$a = \frac{36.6}{n = 10} - \left[\frac{(n-1)}{2}\, b' = 1.413\right] = 2.247$$

Hence, adjusted date of initial epoch of minimum is, 1822.25 years, a date 1.1 years before the observed date.

Final equation, $y = 1822.25 + 11.31x$.

TABLE 3.—*Final results*

Epochs of minima observed	Epochs adjusted Calc.	Difference observed −Calc.
1823.3	1822.2	+1.1
33.9	33.6	+0.3
43.5	44.9	−1.4
56.0	56.2	−0.2
67.2	67.5	−0.3
78.9	78.8	+0.1
89.6	90.1	−0.5
1901.7	1901.4	+0.3
13.6	12.8	+0.8
23.9	24.1	−0.2

Great stress is laid by some writers upon the *variability* of the length of the sun-spot cycle, and a great deal of significance is claimed for the variations. In so far as the one hundred years of observations comprised in the above analysis are concerned *there is a very striking constancy of the period* as shown by the small residuals in Table 3, and it is difficult to see any significance to the slight fluctuations which appear.

In writing down the observations in the two columns I and II of Table 2, it is necessary that the last observation should always stand opposite the first and then the others will pair off together.

When the number of observations is odd the middle observation must, of course, stand alone at the foot of either I or II. It also occurs that the weights in this case are always *even* numbers and end at the foot of the table with 0; that is, the middle observation has no weight whatever in fixing the value of b'.

As a final comment we may suggest that it will rarely be necessary to carry out the calculations for a large number of observations, individually, but rather these may be conveniently grouped in two's, three's, five's, etc., thus reducing the large number to a series of, say, 10 or 20 values. A little judicious planning of the layout of problems suffices to bring almost any problem of this kind within the scope of the simple computations in Table 2.

For the sake of completeness we may write here the basic equations which evaluate a and b' following the calculations in Table 2. The computer needs only to follow the simple rules to which these equations lead without necessarily understanding them clearly.

$$a = \frac{\Sigma c}{n} - \frac{n-1}{2} b' \qquad \text{(A)}$$

$$b' = \frac{2\Sigma xc - (n-1)\Sigma c}{N = [2\Sigma x^2 - \frac{n}{2}(n-1)^2]} \qquad \text{(B)}$$

Now the great simplification comes in (B). Expanding the numerator leads to the combination of the observations into pairs, which can be weighted and summed as in the last column of Table 2. The proper weights are $n-1$, $n-3$, $n-5$, etc., in all cases.

Furthermore, the denominator is always a definite number depending only upon how many observations are used. This denominator, N, together with the sum of squares of the natural numbers from 1 to 25 are easily computed, once for all, and are given in Table 4. The sums of squares are really not needed in the present case, but are given as it is sometimes convenient to have them, and tables containing these values are not very numerous.

TABLE 4.—*Values of N and $\Sigma\, n^2$ for natural numbers 1 to 25*

$[N = \left[2\Sigma x^2 - \frac{n}{2}(n-1)^2\right],\ x = 0, 1, 2, 3, \text{etc.}]$

n	N	Σn^2
1	----------	1
2	1	5
3	4	14
4	10	30
5	20	55
6	35	91
7	56	140
8	84	204
9	120	285
10	165	385
11	220	506
12	286	650
13	364	819
14	455	1,015
15	560	1,240
16	680	1,496
17	816	1,785
18	969	2,109
19	1,140	2,470
20	1,330	2,870
21	1,540	3,311
22	1,771	3,795
23	2,024	4,324
24	2,300	4,900
25	2,600	5,525

ON KRICHEWSKY'S METHOD OF FITTING FREQUENCY CURVES

By EDGAR W. WOOLARD

[Weather Bureau, Washington, D. C., March 10, 1924]

A Law of Facility may be described as the approximate expression of the relative frequency with which, in the long run, different values are assumed by a quantity which is dependent on a number of variable items or elements, given certain conditions which seem to be adequately fulfilled in common experience. For example, the Law of Facility in the familar case of the ordinary errors of observation was exhaustively studied many years ago and has long been accurately represented by the so-called Gaussian curve of errors, the equation of which is well known.

In recent years the great value of being able to derive with quantitative precision the curve which shall exhibit the law of facility of a quantity under consideration has come to be realized to a greater and greater degree in an immense variety of fields of study. In any case the problem is to find from a finite number of observations, which give a more or less irregular frequency polygon or histogram, the curve which approximates most closely to the frequency curve which would result if we could have an infinite number of observations.

We now have several well-known methods of fitting curves to observed frequency distributions. The first difficulty in curve fitting is that of choosing a suitable curve from among all the possible algebraic and transcendental curves that suggest themselves; the second difficulty lies in evaluating the constants of the equation of the adopted curve. Until a comparatively recent date, the great majority of applications of the theory of frequency curves were to errors of precision measurements, which, as mentioned above, usually conform closely to the Gaussian or Normal Law. As a result, the Normal Curve became a Procrustean bed to which all possible measurements had to be made to fit; not until late in the nineteenth century did skew curves gain general recognition.[1] Again, it was for a long time taken for granted that the correct method of evaluating the

[1] See Arne Fisher. *The Mathematical Theory of Probabilities.* Vol. I, 2 ed., pp. 178–187. New York, 1922.

constants or parameters of any curve is the method of least squares, although in nine cases out of ten this method turns out to be impracticable.

The two most important systems of frequency curves now in general use are: (1) The Gram-Charlier curves, developed by Gram, Thiele, Edgeworth, and Charlier, which may readily be fitted with the help of the lucid exposition of Fisher [2] and the tables of Jörgensen.[3] (2) The Pearson curves, for which the necessary directions have been excellently set out by Elderton,[4] and the tables gathered together by Pearson.[5] Three methods of evaluating parameters are in use: (1) Method of least squares; (2) Thiele's method of semi-invariants; (3) method of moments.

Other methods of fitting frequency curves have been proposed from time to time,[6] but have not come into extensive use. The most recent method, and one which appears to have many merits, is that of Krichewsky.[7] The author states that his method has been published in order that it may undergo the test of practical experience over a wide range of problems. It is the purpose of the present reviewer to give enough information concerning the method to enable the nonmathematical reader and those to whom the original paper may not be available actually to fit curves by this process.

Those interested only in actually applying the process may omit the following sketch of the theory and pass at once to the practical directions and illustrative example, merely referring to the numbered formulæ when necessary; the notation is explained again in these directions. It may be noted that the Gamma Functions, which appear in the formulæ, have been tabulated, e. g., in Pearson's Tables, and that no knowledge of their theory is required in order to use these tables, beyond the fact that $\Gamma(x+1)=x\Gamma(x)$.

Mathematical theory.—The frequency curve

$$y=f(x), \tag{1}$$

in which x varies between the limits l_1 and l_2, will have as its area up to any given ordinate

$$z=\int_{l_1}^{x} y\,dx=F(x), \tag{2}$$

the total area being

$$a=\int_{l_1}^{l_2} y\,dx. \tag{3}$$

By the Fundamental Theorem of the Integral Calculus

$$\frac{dz}{dx}=y. \tag{4}$$

The type equation which Krichewsky fits to the observed frequency distribution is

$$\frac{dz}{dx}=kz^m(a-z)^n=\phi(z); \tag{5}$$

This equation expresses the conditions that $y=0$ when $z=0$ and when $z=a$, and that y is a maximum for some value of z between 0 and a. After the values of the three parameters k, m, n have been determined, the integration of (5) gives (2), which upon being differentiated gives (1) by virtue of (4).

A wide range of particular algebraic and transcendental curves is covered by (5). If $m=n=0.7864$, the curve is normal; if m and n are between 0 and -1, J-shaped and U-shaped curves result.

The parameters are evaluated by the method of moments; the moments

$$M_r=\int_0^a yz^r dz$$

of the curve (5) are used for this purpose. Putting

$$p=\frac{M_1}{M_0},\ q=\frac{M_2}{M_1},$$

we find that

$$m+1=\frac{p(a-q)}{a(q-p)},$$

$$m+n+2=\frac{a-q}{q-p}, \tag{6}$$

$$k=\frac{M_0\Gamma(m+n+2)}{a^{m+n+1}\Gamma(m+1)\Gamma(n+1)},\ n\ \textit{positive},$$

$$=\frac{(aM_0-M_1)\Gamma(m+n+3)}{a^{m+n+2}\Gamma(m+1)\Gamma(n+2)},\ n\ \textit{negative}.$$

In virtue of (4), the values of the corresponding moments of the statistics are given by

$$M_0=c\Sigma y^2,\ M_1=c\Sigma y^2z,\ M_2=c\Sigma y^2z^2, \tag{7}$$

c being the class interval.

Equation (5) may be solved by separating the variables, but the integration involved can not in general be performed without the use of series (which do not converge rapidly) unless $m+n$ is a positive integer equal to or greater than 2. (See (5B) below.)

Practical directions for fitting.—1. Prepare the frequency table and histogram in the usual manner. Columns (1) and (2) of Table I give the frequency distribution of rainfall amounts at Washington expressed in the form of ratios to the mean. The successive ordinates of the frequency curve given by observation are those at the midpoints of the classes, at which the class frequencies are assumed to be concentrated [column (3)]; in accordance with custom, divide all the frequencies by the total frequency, and all the class intervals by the class interval, making the total frequency a and the class-interval c each equal to unity; in this way we get the table of abscissae and ordinates given in columns (4) and (5). Column (6) merely assigns consecutive numbers, r, to each observation.

2. Compute the successive areas of the histogram up to each of the r ordinates [column (7)],

$$z_r=\sum_{i=1}^{i=r-1} y_i+\frac{y_r}{2},\quad r=1,\ 2,\ 3\ \cdot\ \cdot\ \cdot \tag{8}$$

3. Compute the quantities given in columns (8)–(11), inclusive; and find the sums of columns (7), (8), (9), (11).

4. The equation which is to be fitted is not that of the frequency curve itself, but

$$\frac{dz}{dx}=kz^m\ (a-z)^n, \tag{5}$$

from which the frequency curve is later derived. The next step is to compute p, q, k, m, n by formulae (6), the quantities M_0, M_1, M_2 being those indicated in Table I.

[2] Arne Fisher, *op. cit.*
[3] N. R. Jörgensen. *Undersögelser over Frequensflader og Korrelation.* Copenhagen, 1916.
[4] W. Palin Elderton. *Frequency-Curves and Correlation.* London, 1906.
[5] Karl Pearson. *Tables for Statisticians and Biometricians.* Cambridge Press, 1914.
[6] See, e. g., J. C. Kapteyn. *Skew Frequency Curves in Biology and Statistics.* Groningen, 1912.
[7] S. Krichewsky. A Method of Curve Fitting. *Ministry of Public Works, Egypt, Physical Department Paper No. 8.* Cairo, 1922.

5. Find $m+n$: (A) If $m+n$ is a positive integer ≥ 2, separate the variables in (5) and integrate; this gives z as a function of x, and upon performing the differentiation (4) we get $y=f(x)$, the equation of the frequency curve. If $m+n$ differs very little from such a positive integer, we may put $n=2-m$ and

$$\frac{m}{2}=\begin{cases}\dfrac{n}{m}, & n<m\\ \dfrac{m}{n}, & m<n\end{cases}$$

in (5), and integrate.

(B) If $m+n$ is not such a positive integer, choose a suitable number of equally spaced values of z from 0 to 1,[8] and compute the corresponding values of $\triangle x$ by the approximate finite-difference formula

$$\Delta x=\frac{\Delta z}{\frac{1}{2}(y_r+y_{r+1})}=x_{r+1}-x_r \tag{9}$$

$$=\frac{z_{r+1}-z_r}{\frac{1}{2}k\{z_r{}^m(1-z_r)^n+z^m{}_{r+1}(1-z_{r+1})^n\}}$$

as shown in Table II. Next find

$$d=\Sigma z/a-0.5. \tag{10}$$

the distance (in class intervals) from the last ordinate of the observed distribution to the ordinate through the mean of this distribution, and calculate the area z_g of the observed distribution up to this ordinate. In general z_g will lie between two of the areas, z_r and z_{r+1}, for which the corresponding theoretical ordinates, y_r and y_{r+1}, and Δx have been computed; compute from (5) y_t the theoretical value of y corresponding to this area, and determine its position relative to y_r by equating $\frac{1}{2}(y_r+y_t)\,\delta x$ (the area of the trapezoid formed by joining the tops of y_r, y_t) to z_g-z_r. Take the position thus determined by δx as origin, and with the aid of the Δx's form a table of corresponding values of z, x, and y, as in Table II (x being in terms of class intervals, and y in terms of the total frequency) from which the curve may be plotted; slight irregularities may result from the use of (9).

The area of the fitted curve is equal to the area of the statistics, and the centers of gravity of the two distributions coincide. The mode is given by $z=ma/(m+n)$.

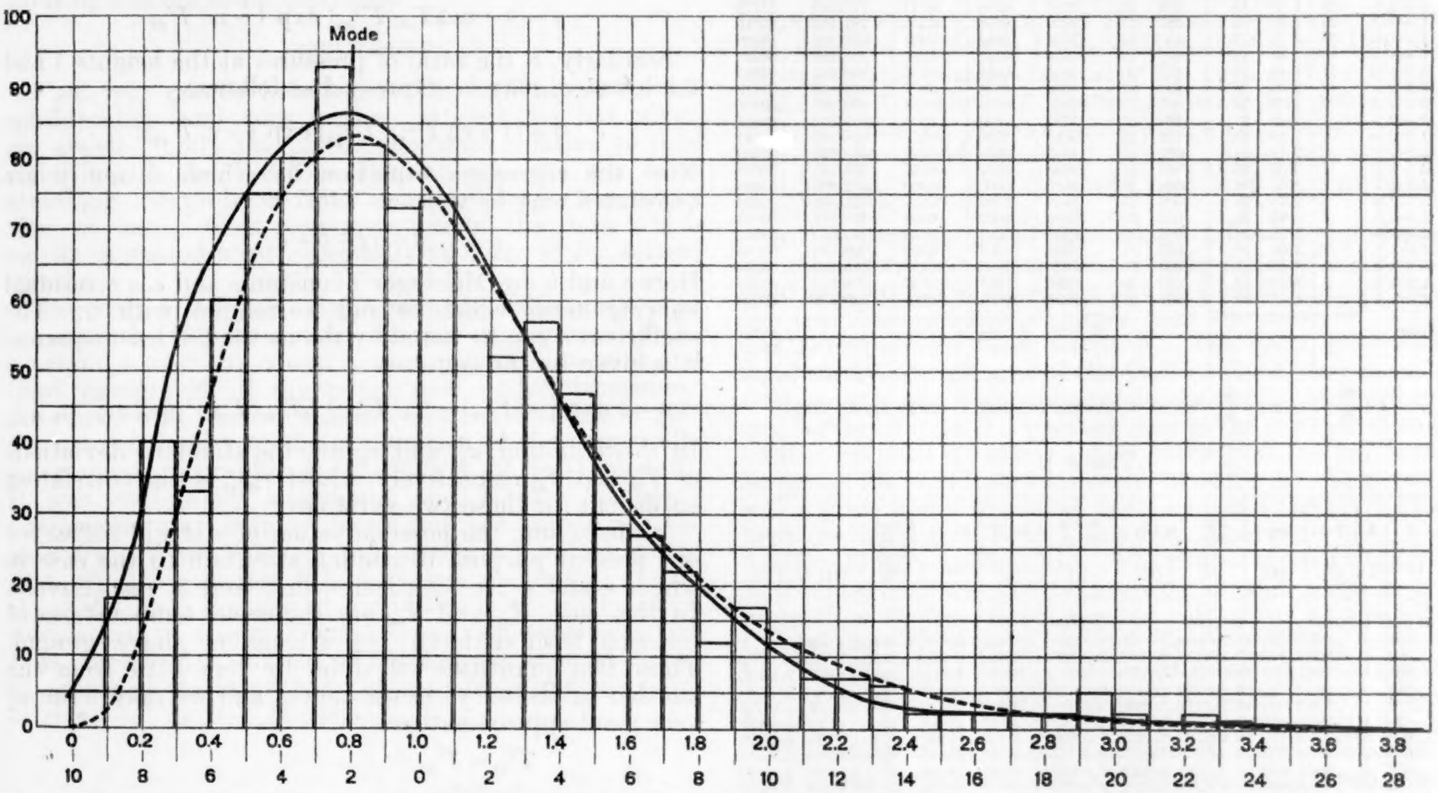


FIG. 1.—Histogram and frequency curve of Washington (D. C.) rainfall data (see Table I). Solid curve: Krichewsky curve of closest fit; dotted curve: Pearson curve (Type III) of closest fit.

In case (B) it is not possible to find an *equation* for the frequency curve itself; but in all cases the ordinates corresponding to any given *areas* can easily be found from (4) and (5). Pearson's system gives the equation to the frequency curve in all cases, but in general these equations cannot be integrated; and areas, which are often what is really desired, cannot be found without great labor. The arithmetical work in fitting the curve is much more laborious in Pearson's system than by the present method. The resulting fits by the two methods appear to be equally good; a number of examples are given by Krichewsky. The best-fitting Pearson curve for the data in Table I is that of Type III given by the equation—

$$y=834.3\left(1+\frac{x}{0.782}\right)^{2.835}\exp\,(-3.626x).$$

The accompanying Figure 1 shows both curves and the histogram.

[8] In order to carry the fit out to the limits of the observed distribution it is necessary to choose these values much closer together near 0 and 1 than in the middle.

TABLE I

Class (1)	Freq. (2)	Mid-points (3)	x (4)	y (5)	r (6)	z (7)	$y^2 \times 10^2$ (8)	$y^2z \times 10^2$ (9)	z^2 (10)	$y^2z^2 \times 10^2$ (11)
0.0-0.1	5	0.05	0.5	0.005	1	0.0025	0.0025	0.00000	0.0000062	0.00000
0.1-0.2	18	0.15	1.5	.018	2	.0140	.0324	.00045	.0001960	.00000
0.2-0.3	40	0.25	2.5	.040	3	.0430	.1600	.00688	.0018490	.00029
0.3-0.4	33	0.35	3.5	.033	4	.0795	.1089	.00865	.0063202	.00069
0.4-0.5	60	0.45	4.5	.060	5	.1260	.3600	.04536	.0158760	.00572
0.5-0.6	75	0.55	5.5	.075	6	.1935	.5625	.10884	.0374422	.02106
0.6-0.7	80	0.65	6.5	.080	7	.2710	.6400	.17344	.0734410	.04700
0.7-0.8	93	0.75	7.5	.093	8	.3575	.8649	.30920	.1278062	.11054
0.8-0.9	82	0.85	8.5	.082	9	.4450	.6724	.29922	.1980250	.13315
0.9-1.0	73	0.95	9.5	.073	10	.5225	.5329	.27844	.2730062	.14548
1.0-1.1	74	1.05	10.5	.074	11	.5960	.5476	.32637	.3552160	.19452
1.1-1.2	55	1.15	11.5	.055	12	.6605	.3025	.19980	.4362602	.13197
1.2-1.3	52	1.25	12.5	.052	13	.7140	.2704	.19306	.5097960	.13785
1.3-1.4	57	1.35	13.5	.057	14	.7685	.3249	.24968	.5905922	19188
1.4-1.5	47	1.45	14.5	.047	15	.8205	.2209	.18125	.6732202	.14871
1.5-1.6	28	1.55	15.5	.028	16	.8580	.0784	.06727	.7361640	.05772
1.6-1.7	27	1.65	16.5	.027	17	.8855	.0729	.06455	.7841102	.05716
1.7-1.8	22	1.75	17.5	.022	18	.9100	.0484	.04404	.8281000	.04008
1.8-1.9	12	1.85	18.5	.012	19	.9270	.0144	.01335	.8593290	.01237
1.9-2.0	17	1.95	19.5	.017	20	.9415	.0289	.02721	.8864222	.02562
2.0-2.1	12	2.05	20.5	.012	21	.9560	.0144	.01377	.9139360	.01316
2.1-2.2	7	2.15	21.5	.007	22	.9655	.0049	.00473	.9321902	.00457
2.2-2.3	7	2.25	22.5	.007	23	.9725	.0049	.00476	.9457562	.00463
2.3-2.4	6	2.35	23.5	.006	24	.9790	.0036	.00352	.9584410	.00345
2.4-2.5	2	2.45	24.5	.002	25	.9830	.0004	.00039	.9662890	.00039
2.5-2.6	2	2.55	25.5	.002	26	.9850	.0004	.00039	.9702250	.00039
2.6-2.7	0	2.65	26.5	.000	27	.9860	.0000	.00000	.9721960	.00000
2.7-2.8	2	2.75	27.5	.002	28	.9870	.0004	.00039	.9741690	.00039
2.8-2.9	2	2.85	28.5	.002	29	.9890	.0004	.00039	.9781210	.00039
2.9-3.0	5	2.95	29.5	.005	30	.9925	.0025	.00248	.9850562	.00246
3.0-3.1	2	3.05	30.5	.002	31	.9960	.0004	.00040	.9920160	.00040
3.1-3.2	0	3.15	31.5	.000	32	.9970	.0000	.00000	.9940090	.00000
3.2-3.3	2	3.25	32.5	.002	33	.9980	.0004	.00040	.9960040	.00040
3.3-3.4	1	3.35	33.5	.001	34	.9995	.0001	.00010	.9990002	.00010
Sums						23.9220	5.8786 M_0	2.62878 M_1		1.48254 M_2

$p=\frac{M_1}{M_0}=0.4472$; $q=\frac{M_2}{M_1}=0.5640$; $m=0.6695$; $n=1.0634$; $k=0.2743$; $m+n=1.7329$.

TABLE II

z (1)	k (2)	$1-z$ (3)	$\log z$ (4)	$\log (1-z)$ (5)	$m \log z$ (6)	$n \log (1-z)$ (7)	$\log y$ (8)	$y \times 10$ (9)	$\frac{1}{2}(y_k+y_{k+1}) \times 10$ (10)	Δx (11)	x (12)
0.000	0	1.000	------	0.00000	------	0.000000	------	------	------	------	------
.001	1	.999	7.00000	9.99956	4.686500	10.633532	7.42926	0.02687	0.0348	0.28736	------
.002	2	.998	7.30103	9.99913	4.888039	10.633075	7.63034	.04269	.0552	.36232	10.17562
.004	3	.996	7.60206	9.99826	5.089579	10.632150	7.83096	.06776	.0782	.25575	9.88826
.006	4	.994	7.77815	9.99739	5.207471	10.631224	7.94792	.08870	.1065	.37559	9.52594
.010	5	.990	8.00000	9.99564	5.356000	10.629364	8.09459	.12434	.1600	.62500	9.27181
.020	6	.980	8.30103	9.99123	5.557539	10.624674	8.29144	.19563	.2247	.44504	8.89622
.030	7	.970	8.47712	9.98677	5.675432	10.619931	8.40459	.25386	.2791	.35829	8.27122
.040	8	.960	8.60206	9.98227	5.759079	10.615146	8.48345	.30440	.3270	.30581	7.82618
.050	9	.950	8.69897	9.97772	5.823960	10.610307	8.54350	.34954	.4372	1.14364	7.46789
.100	10	.900	9.00000	9.95424	6.025500	10.585339	8.72006	.52488	.5864	0.85266	7.16208
.150	11	.850	9.17609	9.92942	6.143392	10.55894[illegible]	8.81156	.64798	.6923	.72223	6.01844
.200	12	.800	9.30103	9.90309	6.227040	10.530946	8.86721	.73656	.7675	.65146	5.16578
.250	13	.750	9.39794	9.87506	6.291921	10.501139	8.90228	.79851	.8184	.61095	4.44355
.300	14	.700	9.47712	9.84510	6.344932	10.469279	8.92344	.83838	.8487	.58914	3.18114
.350	15	.650	9.54407	9.81291	6.389755	10.435048	8.93403	.85907	.8609	.58079	2.59200
.400	16	.600	9.60206	9.77815	6.428579	10.398085	8.93580	.86276	.8569	.58350	2.01121
.450	17	.550	9.65321	9.74036	6.462824	10.357899	8.92995	.85104	.8381	.59659	1.42771
.500	18	.500	9.69897	9.69897	6.493460	10.313885	8.91657	.82522	.8058	.62050	0.83112
.550	19	.450	9.74036	9.65321	6.521171	10.265223	8.89562	.78636	.7609	.65712	0.26062
.600	20	.400	9.77815	9.60206	6.546471	10.210831	8.86653	.73541	.7043	.70992	0.86774
.650	21	.350	9.81291	9.54407	6.569743	10.149164	8.82813	.67318	.6368	.78518	1.57766
.700	22	.300	9.84510	9.47712	6.591294	10.077969	8.77849	.60047	.5592	.89413	2.36284
.750	23	.250	9.87506	9.39794	6.611353	9.993769	8.71435	.51802	.4723	1.05865	3.25697
.800	24	.200	9.90309	9.30103	6.630119	9.890715	8.63006	.42664	.3769	1.32661	4.31562
.850	25	.150	9.92942	9.17609	6.647747	9.757854	8.51483	.32721	.2741	1.82415	5.64223
.900	26	.100	9.95424	9.00000	6.664364	9.570600	8.34419	.22090	.1652	3.02663	7.46638
.950	27	.050	9.97772	8.69897	6.680084	9.250485	8.03980	.10960	.0870	2.29885	10.49301
.970	28	.030	9.98677	8.47712	6.686142	9.014569	7.80994	.06456	.0424	4.71698	12.79186
.990	29	.010	9.99564	8.00000	6.692081	8.507200	7.30851	.02035	.0151	3.31126	17.50884
.995	30	.005	9.99782	7.69897	6.693540	8.187085	6.98998	.00977	.0077	2.59710	20.82010
.997	31	.003	9.99869	7.47712	6.694123	7.951169	6.75452	.00568	.0037	5.40541	23.41720
.999	32	.001	9.99956	7.00000	6.694705	7.443800	6.24773	.00177	------	------	28.82261
1.000	33	.000	0.00000	------	0.000000	------	------	------	------	------	------

COMMENTS ON THE LAW OF PRESSURE RATIOS

By F. J. W. WHIPPLE

[6 Addison Road, Chiswick, London, W 4, January 2, 1924]

In his paper on "The Law of Pressure Ratios and its Application to the Charting of Isobars in the Lower Levels of the Troposphere," Dr. C. Le Roy Meisinger has reached conclusions to which he has given some prominence but which seem to be based on insufficient evidence. The object of this letter is to point out that the argument by which Doctor Meisinger shows that there is a functional relation between his variables x and y shows also that there is an upper limit to the constant which he calls a.

It is convenient to make a small change from Meisinger's notation and write T_{oz} for the average value of the absolute temperature between the heights s and z.

By definition y is the ratio of pressures at the heights z and s kilometers above sea level so that $y=\exp(-zc/T_{sz})$, where c is a constant.

If T'_{sz} is the mean value of T_{sz} and ΔT_{sz} the departure from the mean, then,

$$y=[1+zc\Delta T_{sz}/T'^2_{sz}] \exp(-zc/T'_{sz}).$$

Similarly, x, the ratio of pressures at the heights 1 and 2 kilometers may be expressed as follows:

$$x=[1+c\Delta T'^2_{12}/T'^2_{12}] \exp(-c/T'_{12}).$$

Now the regression equation by which x and y are associated may be written

$$y=ax+b+\epsilon.$$

Here a and b are Meisinger's constants and ϵ is a residual varying term which is not correlated with x. The coefficient a can be found by the method of least squares: it is given by the equation

$$a=z \exp[(c/T'_{12})-(c_z/T'_{sz})] (T'_{12}/T'_{sz})^2 (\sigma_{sz}/\sigma_{12}) r_{sz.12}$$

In this equation, σ_{sz} and σ_{12} are the standard deviations of T_{sz} and T_{12} respectively, whilst $r_{sz.12}$ is the correlation coefficient for those two variables.

In discussing the possible values of a it will suffice for our present purpose to confine attention to the case in which s and z are identical with 0 and 3, respectively. In this case, T_{12} and T_{sz} are the mean temperatures of columns both centered $1\frac{1}{2}$ kilometers above ground. These two quantities will differ by very little from one another in ordinary circumstances and we may write as very good approximations:

$$T'_{12}=T'_{03}$$
$$\sigma_{12}=\sigma_{03}$$
$$A=3 \exp(-2c/T'_{12}) r_{03.12}$$

For T'_{12} we may take the annual mean for the United States[1] $T'_{12}=279$

It follows[2] that $\exp(-c/T'_{12})=:8847$ and hence that

$$A=3\times :8847^2 r_{03.12}=2.35 r_{03.12}$$

Now the correlation coefficient must be near to unity but it can not exceed unity. Hence 2.34 is the upper limit for the coefficient a for 3 kilometers.

The values obtained by Doctor Meisinger at two of his stations are 2.58 and 2.76, respectively. These figures seem to be too high; they could only be justified by the supposition that σ_{03} exceeded σ_{12} considerably. This might happen if the series of observations included a large number of "inversions" of temperature but the available evidence is against this supposition. The tables for the stations in question, Groesbeck and Leesburg in Gregg's "Aerological Survey of the United States" do not show any excessive frequency of cold air at the surface and moreover the observations which were utilized both by Gregg and by Meisinger were

[1] Gregg: *Aerological Survey of the United States.* MO. WEATHER REV. SUPP. NO. 20, Table 6.
[2] *Computer's Handbook*, London, 1917. 11.2.44.

made with kites and could not have been obtained in the calm air which occurs with inversions. Thus it appears that the results obtained by Doctor Meisinger for the two stations in question can not be accepted without further investigation.

If these data be rejected then the variations in Meisinger's coefficient a are so insignificant that the characteristic features of his charts disappear. This would in fact be an advantage; for a general formula applicable to all parts of the region would be preferable to one suitable only for use within narrow limits.

I trust that Doctor Meisinger will find an opportunity to reexamine the results which have been called in question and that he will let it be known how the anomalous figures are to be explained.

DISCUSSION

I am very greatly indebted to Doctor Whipple for the consideration and constructive criticism he has given my article. Only the pressure of work relative to field activities of the Weather Bureau prevents me from attacking the problem from Doctor Whipple's point of view at once. This reexamination of the data which he has suggested must necessarily be deferred for several months.

The very gratifying thing about the criticism is that it points the way to a more equable distribution of the constant a over the country. On page 446, second and third paragraphs of my paper now under discussion,[3] the reader will observe that no effort was made to give the tone of finality to the explanation of the empirically determined geographical distribution of this constant. It was confessedly anomalous and Doctor Whipple's suggestions may help to ferret out the reason for the anomaly. While it is true that two of my values exceed that given by Doctor Whipple as a maximum, I may say that I have the utmost confidence in the arithmetical calculations by means of which those values were derived. It is, therefore, a matter of the keenest interest to me to approach the same body of data from another point of view.—*C. Le Roy Meisinger.*

[3] Mo. WEATHER REV., September, 1923, 51: 437–448.

PROBLEMS OF THE LOWER COLORADO RIVER

By JAMES H. GORDON

[Weather Bureau, Yuma, Ariz., December, 1923]

The lower Colorado River is roughly defined as that portion of the stream below the 500 foot contour. It embraces some 350 miles of channel extending from the southeastern corner of Nevada to the Gulf of California. Along the lower third of this distance the river flows through its delta. It is in this delta country that most development has taken place and here, naturally, most of our problems have arisen.

The Colorado River as it comes to us out of the hills is a quiet and naturally law-abiding stream 10 months of the year. For the other two months it ceases to be quiet and is law abiding only because of strong levees that hold it in restraint. During this period, the time of the spring floods, it becomes a powerful, turbulent river. It is then a threat against every bit of development along its banks.

There is but one important tributary entering the lower Colorado. This is the Gila River. It is a typical southwestern stream flowing "sandy side up" most of the time but capable of staging floods of very serioue proportions occasionally. Fortunately, these floods come during the winter months and within the memory of man, at least, have never coincided with high water in the Colorado. Both the Gila and Colorado are hard working streams. Joining just above Yuma they bring down in an average year some 6,000,000 carloads of silt and sand, a hundred thousand acre-feet of soil, for their delta building.

Having this introduction to the river itself we may turn to its problems. One of them is of especial interest not only because of its importance to the delta country but because it is unique among the river problems of the United States if not of the world. The problem is best understood if traced back to its beginning. The beginning was a good many thousand years ago, about the time the Colorado River emerged from the hills to the north and joined forces with the Gila at Yuma. At that time the Gulf of California extended some 150 miles north of its present limits with an eastward extension to the neighborhood of Yuma. Into this eastern arm of the Gulf the Colorado and Gila poured their muddy waters. (See fig. 1.)

In the long period of time which followed the rivers brought down many hundreds of cubic miles of rock and sand and mud, the scourings of the Grand Canyon and the ten thousand lesser gorges, and the wash-off from 240,000 square miles of territory. The delta grew and filled in the eastern arm of the Gulf. The Colorado and Gila became one river and pushed the delta head farther and farther out until it reached clear to the western shore; built it up until it formed a dam cutting off the northern section of the Gulf from the ocean. (See fig. 2.) This, too, was a good many thousand years ago and the river has kept on building. To-day the dam, above sea level, is nearly a hundred miles wide. The course of the Colorado River lies between the twin crests of this delta cone more than 30 feet above the sea. It turns to the left toward the Gulf, 50 miles away. To the right lies the old sea bed, the Salton Basin, its lowest point more than 300 feet below the river level and but 70 miles away. (See fig. 3.)

One must wonder that the river takes the sluggish way to the Gulf instead of a grade nearly ten times as steep into Salton Basin. It is true that now there are levees to prevent its turning north, but long before the levees were built the river was taking the sluggish course rather than the steep one.

There is little question that the Colorado River has flowed into the Salton Basin a number of times during the last 10,000 years, turned from the Gulf to the old sea bed. Such a change stirs one's imagination. There would be the gradual preparation, the south side of the river building up a little higher each year with an added layer of silt, the north bank cut increasingly by overflow at flood time; then finally at some high water a cut would reach back clear through the north bank to the main channel, the river would feel the urge of the steeper grade and turn roaring onto the desert. It would be something to see, this turning of a mighty river into the dry, barren old basin, the growth of a sea in the desert, the blotting out of a million acres of sand. In 30 or 40 years the basin would be full to the brim, probably with an outlet to the Gulf to carry off the high waters of flood time. But the grade would be gone. Instead of roaring out onto the desert the river would flow sluggishly into a quiet sea to drop its load and start in again on the old business of delta building. With the passing years the river would shift back and forth, east and west, as a

delta cone became a dam and the river sought an easier channel. It is hard to say how long this would take, the building up of the north bank to the danger point,

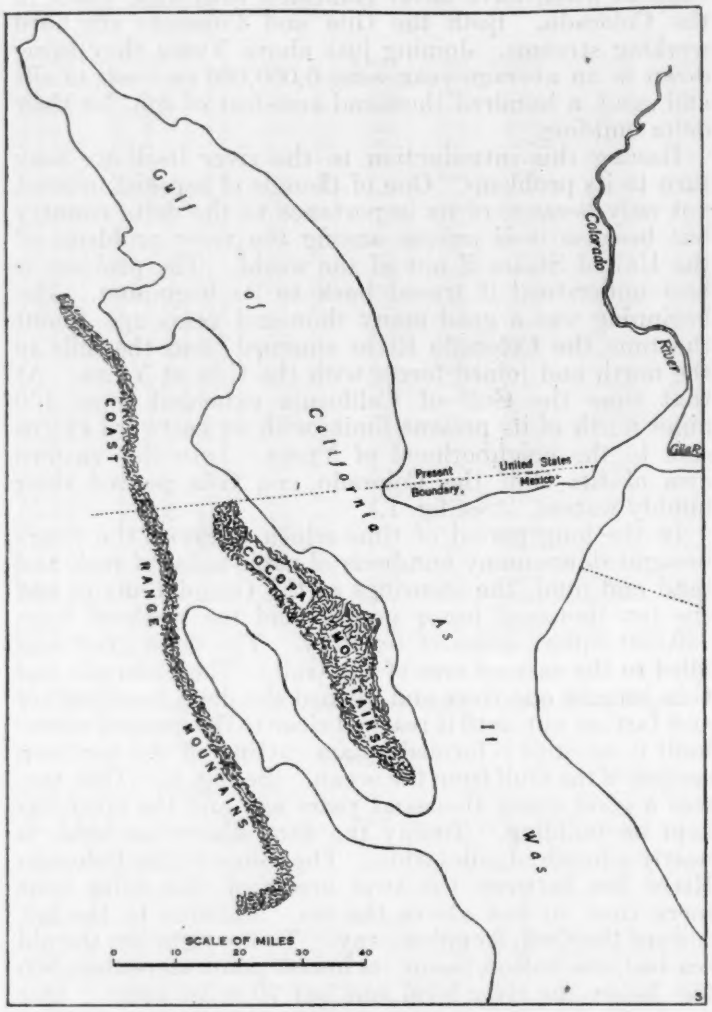


FIG. 1.—Gulf of California and adjacent country several thousand years ago

probably three or four hundred years at least. Eventually, inevitably, at some high water a break would come in the south bank, for any grade is better than none, and the river would turn again toward the Gulf, to start the damming process all over again.

Something less than a thousand years ago, geologists tell us, the last shift into the south took place. For many years the Colorado River had flowed into the Salton Basin. Indian villages lay along its shores, the people living by fishing and growing corn on the overflow land following each high water. Then, the building up of the north bank being sufficient, the river turned south and the desert crept back as the sea shrunk away to nothingness. It was a great catastrophe to the fisher people. They were driven away to find other homes. Traces of the old villages still remain.

For nearly a thousand years the Salton Basin lay empty, a sun-baked, barren desert (fig. 4). So white men found it and hated its glaring desolation. Some 70 years ago an Army engineer proposed to re-create the sea, to turn the Colorado River into the Salton Basin again. His plans came to nothing but other men came after him with other plans. It was 50 years before the plans bore fruit. Twenty-two years ago men turned the waters of the Colorado River back into the Salton Basin and a sea appeared in the desert. But this was not like the sea which had evaporated a thousand years before. It was a sea of green, miles and miles of alfalfa fields, thousands of acres of cotton and grain, great acreas of melons, vineyards, truck farms, and fruits. Cities grew up in the midst of it. The new sea in the desert supports a population probably a hundred times as great as the Indian villages could boast. More than three-quarters of a million acres of land have come under cultivation.

Here then is our problem. The Colorado River flowing along the crest of a ridge turns to the left to follow a sluggish way to the Gulf. To the right is the Salton Basin, its lowest point but a little farther from the river than the Gulf and offering a drop ten times as great. Now the old sea bed is not a hated desert to be gratefully blotted out by a new sea but a rich agricultural empire worth a hundred millions of dollars and providing homes for 50,000 people. It is one of the ironies of nature that the Colorado River drove man from the Salton Basin a thousand years ago by turning to the Gulf while to-day it would drive him out by returning to the Salton Basin. For all these years the river has been flowing into the south it has been forcing back the head of the Gulf, building up the country, flattening out its grade, and the cycle seems almost completed. The Colorado River is ready to turn again into the Salton Basin and blot out the civilization of to-day as it blotted

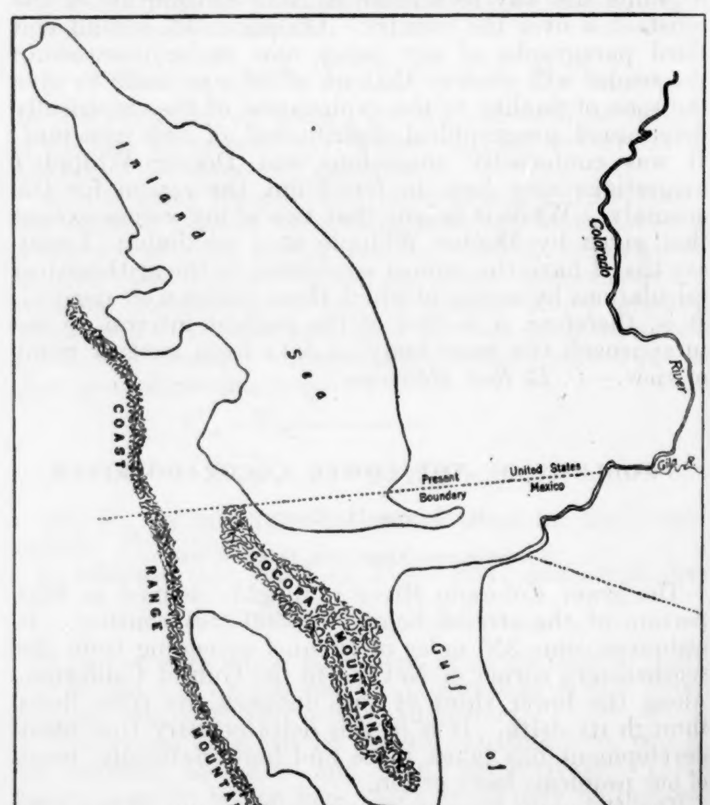


FIG. 2.—Later changes in the Gulf of California and adjacent country. (See fig. 1.)

out the desert of yesterday. This is *the* great problem of the lower Colorado, the problem of a river tremendously powerful during its annual flood period ready with

FIG. 4.—A sand-hill area 5 miles wide and 40 miles long marks the eastern boundary of the Salton Sink

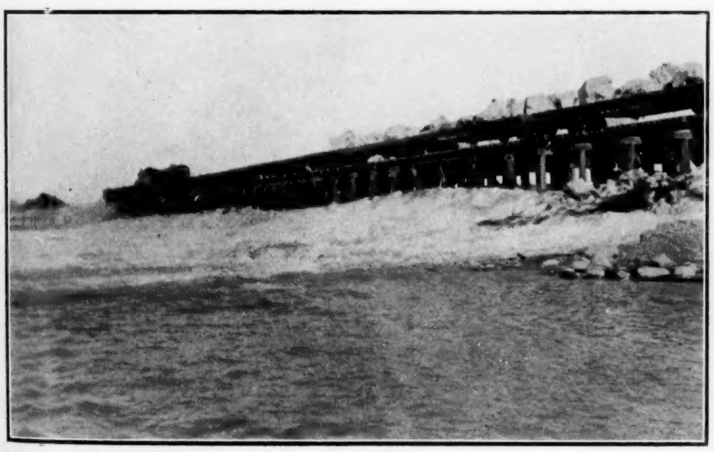


FIG. 5.—Trying to check the break of 1905. It was finally closed at a cost of over $2,000,000

FIG. 6.—During the break of 1905-6 the New and Alamo Rivers cut back from north toward the Colorado ,forming channels 50 to 60 feet deep

FIG. 7.—West bank of the New River Canyon, 4½ miles west of Brawley, Calif., August 30, 1906. This canyon was created by the break of 1905-6 and is nearly 70 miles long

FIG. 8.—Headgates of the Imperial Canal through which some 3,593,000,000 gallons of water flow daily

the preparation of a thousand years to turn its flow back into the old sea bed.

In former times man was powerless before the river; now with the weapons of our modern civilization at his hand man is no mean adversary even for the mighty Colorado. In 1905 the river tore away the intake of the Imperial Irrigation Co. Canal and sent its whole flow into Salton Sink. After 16 months of effort the break was closed at a cost of over $2,000,000 and the river again flowed south. (Figs. 5 and 6.) In 1909 the Colorado again turned west following the old channel of Bee River to Volcano Lake. Early in 1911 a levee was completed blocking the Bee channel, money for the work having been provided by the Congress of the United States, but high water a few months later tore away this levee and the river again flowed into Volcano Lake.

The defenders dropped back to this new line and built up a strong system of defense. Experience had convinced engineers of the futility of opposing the river with dirt levees and rock revetment was used as far as practicable. The defenses, reinforced every year, held well but the river flowing into the Volcano Lake basin dropped much of its load, filled in the bed of the lake and year by year raised the plane of attack. In 1921 the assault was so fierce that the flood waters lapped the ties of the railroad along the levee crest. It is said that only a shift of wind that drove the waters back a little saved the day. At least the levees held. But the line was too dangerous. A break in the Volcano Lake defenses would send the river into the channel of the New River, already deep scoured by the break of 1905 (fig. 7.)

During the low water period which followed a flank attack was made on the Colorado. At a favorable point 8 miles east of Volcano Lake a cut 4 miles long was dredged in the south bank, piercing the broad crest of the delta cone and reaching lower land. A strong rock fill dam was thrown across the old channel forcing the river into the new. This area south of the river was normally flooded by overflow at high water and a drainage system had developed known as the Pescadero River. It was hoped that the Colorado would take one of the tributaries of the Pescadero, scour it out and make a good channel through from the cut to the Hardy Colorado. This new channel would shorten the distance to the Gulf by several miles, offer a somewhat better grade than the old course and, it was expected, relieve the strain on the north bank for a number of years.

The high waters of 1922 and 1923 were carried successfully but the hoped-for channel had not been made. Instead the river, following its old custom has spread out, lost velocity and is building up a delta at the southern end of the cut. In 1923 gage readings above the cut were a foot higher than for the same discharge in 1922. Levees, discarded for new lines, which held the river in 1922 were overtopped in 1923. This is a brief history of the problem to date. There has been no break into the Salton Basin since 1906 but at every high water there is threat of one. On the holding of a long, thin line of granite-faced levees depends the safety of the Salton Basin country.

A break would be a very serious matter. That of 1905 cut a network of channels which converged into the New and Alamo Rivers. The channels of these rivers scoured back from the north to a depth of from 50 to 60 feet, the New River to near Volcano Lake and the Alamo to near the international boundary. A new break if it cut one of these channels back to the main river would offer a tremendous problem. The cut if long unchecked would work back up the river for miles dropping the river level many feet, quite possibly threatening the security of Laguna Dam. To turn the flow south again the river would have to be dammed and lifted up out of this deep channel. In a land of bottomless silt dam building under the most favorable circumstances is not easy. Even supposing the break stopped our problem is not solved. The deep cut channels of one break only make the threat of another more menacing. So the matter stands. The river is bringing down its 6,000,000 carloads of silt and sand a year, a hundred thousand acre-feet of damming material. During the last year engineers, to balance this, threw in 6,000 carloads of rock to keep their lines safe. The problem is being met and met bravely but it is not solved. Each year the threat of diasaster is renewed.

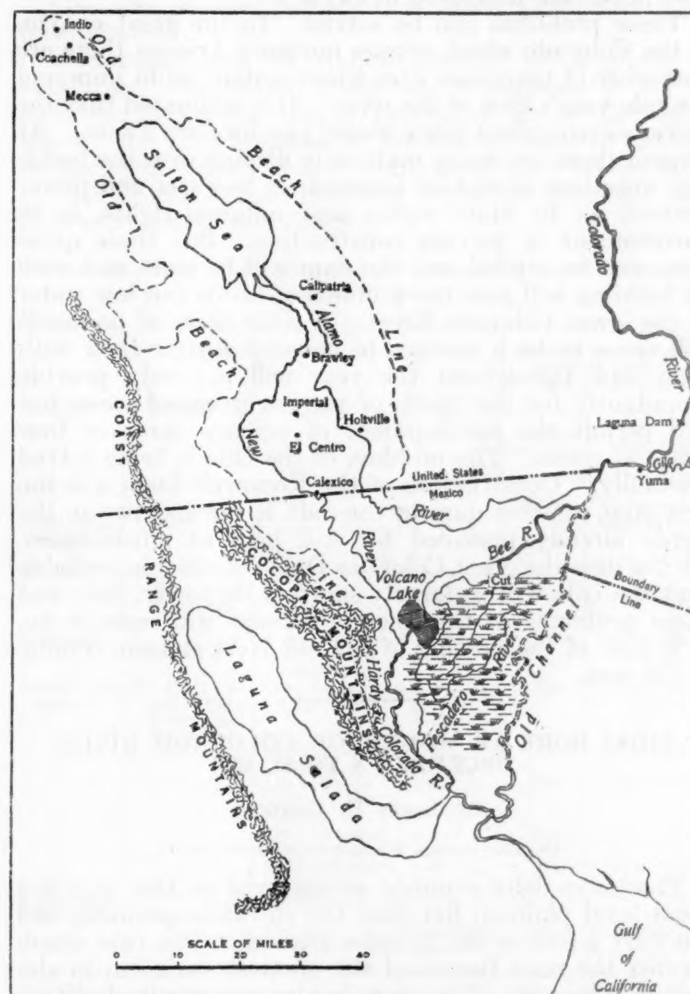


FIG. 3.—Gulf of California and adjacent country to-day. (See figs. 1 and 2.)

This is our chief problem of the lower Colorado. Others are secondary. This is a problem of floods. Oddly enough one of the others is lack of enough water. Three months after we have seen the millions of acre-feet of water go tearing by to the Gulf, utter waste, the Colorado has ceased to be a big river. Quite a number of times in the last 20 years it has become so small a stream that the entire flow reaching the Imperial Canal (fig. 8) intake fell below present irrigation demands. Safe development of the country is limited by the minimum flow of the river. Construction of the all-American Canal is held not justified under this limitation.

The Gila River is our third problem. The floods of the Colorado come at a definite time each year. Every year the organization is ready—men, cars, locomotives,

steam shovels, supplies. As the river rises slowly any weak point in the defences is noted and reinforcement rushed in. The Gila on the contrary is a flashy stream. A big, general rain over Arizona, especially if it finds snow to melt, will start a flood overnight. In January, 1916, the flow of the Gila, entering the Colorado just above Yuma, increased from 1,300 second-feet to nearly 200,000 second-feet in five days. There is little time to prepare for such a flood, to build up an organization to fight it. Dangerously high stages in the Gila have occurred but three times in the last 20 years. Fortunately the river drops almost as fast as it rises. A break in the levees may cause damage but it can be soon mended. Where the Colorado floods are formidable for weeks, the Gila floods are measured in days.

These problems can be solved. In the great canyon of the Colorado which crosses northern Arizona there are a number of favorable sites where a dam could impound a whole year's flow of the river. It is estimated that the power development alone would pay for such a dam. At present there are many matters in dispute over the building, questions as to best location, as to water and power control, as to State rights and national rights, as to Government or private construction. But these questions can be settled and the dam will be built, and with its building will pass the problem of floods and low water in the lower Colorado River. A river shorn of its floods will cease to be a menace to development; a river with even flow throughout the year will not only provide abundantly for the needs of present irrigated areas, but will permit the development of acreage three or four times as great. The problem of the Gila is being solved gradually. Construction of the Roosevelt Dam was the first step, another dam in the Salt River and two in the Verde already provided for will help as much again. By the time the great Colorado Dam is built it is probable that the Gila will be largely shorn of its power, also, and these problems of the lower Colorado will cease to be. It is part of the passing of the old West and the coming of the new.

TIDAL BORE AT MOUTH OF COLORADO RIVER DECEMBER 8 TO 10, 1923

By JAMES H. GORDON

[Weather Bureau, Yuma, Ariz., December 1923]

The lower delta country, as observed on this trip, is a great level plain so flat that the elevation probably did not vary a foot in the 25 miles crossed. The ruts which formed the road furnished the greatest variation in elevation observed. The plain is almost entirely destitute of plant growth. A liberal estimate would be one small bush to every hundred acres. There was a strong wind blowing. My hat went off. One of the men sprang after it, but was distanced. Because of recent rains it was unsafe to leave the road and follow "cross country." We did not follow the road which trended southeast while the hat went straight south. The hat was kept in sight for more than 3 miles and in that distance there had not been so much as a bush to check it in its mad flight. This to illustrate the character of the country. There are no recognizable channels across it except occasional drainage lines a few inches deep. Water from the Colorado at flood times and from overflow tides must cross this plain to reach Laguna Salada, which they are supposed to feed. The elevation of the plain is given as 8 feet at the northern end and 7 a little distance south of La Bomba.

While crossing this open country Pinto Mountain was observed. It is an isolated peak 1,500 to 1,800 feet high, rising abruptly from the western edge of the plain just south of the entrance to Laguna Salada. It is normally dark in color with its steep slopes grotesquely spotted with big patches of sand, some probably fully an acre in extent. Apparently the high north winds blowing down the Laguna Salada Valley pick up nearly their maximum load of sand. Eddies and swirls on the lee side of the mountain check the wind velocity enough to cause a dropping of the sand load. Time did not permit a close study of the mountain.

About 3 miles from La Bomba the road ran into water. It was shallow but extensive, so we left the cars and waded. The water was nowhere more than 6 inches deep, underlaid with a very adhesive mud, and covered perhaps half of the distance. A few "islands" were fairly dry. The rest of the way was mud. The water came from a tidal overflow of two nights previous and would require, we were told, two more days to drain off.

The "city" of La Bomba, the "seaport" of this section of Mexico with two small steamers a week, consists of seven small buildings, including a radio station, and at the time of our visit boasted five inhabitants and seven automobiles and trucks. The "port" is a slushy, crumbling river bank. I did not witness the method of unloading freight but with a normal tidal range of fully 12 feet, strong river and tidal currents and only a crumbling mud bank to work from it must present many difficulties. The freight brought in is mostly liquor for the border towns while fish are shipped south. The "city" is flooded about 6 inches deep every new moon, we were told, and at times of high water in the river it is cut off for weeks at a time. It is soon to be linked with Maxicali by Government-built railroad, much of the grading has been done, but it can never be much of a port. At present it seems to be the only point which may be reached by automobile from which the bore may be observed.

We reached La Bomba at 11.30 a. m. December 9. A strong, cold north wind was blowing and having taken the lay of the land, measured the height of the bank and set stakes by which to judge the bore we took shelter in the lee of one of the houses. A mountain chain of many interlocking ranges lies some 8 miles to the west and was remarkably impressive and beautiful in the sandstorm haze. From our shelter it was possible to see some distance down the river.

The coming of the bore was first called to our attention by the disturbance among a big flock of white pelicans fully 6 miles away. Fish always follow the bore in, we were told. The brown line of the bore itself was visible with the glass at perhaps 3 miles. Its speed appeared to be nearly 8 miles an hour. As a spectacle it was disappointing. This was doubtless due in some measure to the strong north wind that had been fighting the tide all the way up the Gulf. Up to the moment that the bore, or first wave, arrived the current was running strongly seaward. In an instant it was reversed and racing up the river. The bore was not over 3 feet high, a racing wave fully a mile long, foam crested and perhaps a foot higher over the shallows and sand bars. In deep water it was like a ground swell apparently running *over* the outgoing tide and river current. The *lack of turmoil between the two opposite currents was surprising.* The level of the river rose 3 feet in the first minute and 5 feet in 15 minutes. The bank was 15 feet high at low tide. The high tide of two nights previous had filled the channel and overflowed the surrounding country 6 inches

deep. Probably a full half mile behind the first wave something similar to a tide rip appeared, waves 3 to 4 feet high probably not over 20 feet from crest to crest racing up the river. They would have made very rough going for a small boat.

As contrasted with the bore we saw it is said that the first wave is 10 feet high at times. In September, 1922, a small steamer was wrecked by the bore and succeeding waves, with a loss of 130 lives. That is the sort of bore we did not see.

Because of the need of getting back to Calexico that night we did not wait to see the high tide.

Returning from Calexico to Yuma the next day the two other Yuma members of the party and I had opportunity to see the effect of the worst windstorm in years on the sand hills. Where the road crosses this "Sahara of America" the sand-hill area is about 5 miles wide. An eight foot plank road has been built through this section which would otherwise be impassable and an average of about 200 cars pass over it daily. The shifting sands have always been a problem and men with teams and scrapers are maintained at all times to keep the road clear. This storm had been too much for them. Tongues of sand crossed the road in perhaps a hundred places. Where they were not over a foot or 18 inches deep the car took them on the rush but over the most exposed portion of the road the sand drifts were 4 or 5 feet deep. Some 60 cars were tied up when we arrived, some of them had been there 24 hours and our stock of provisions left from trip was quickly disposed of. To the east it was 10 miles to food and water, to the west 5 miles to the headquarters of the road workers. The wind was blowing a gale and the sand was going with it. I have long wanted to watch a storm in the sand hills. This opportunity was ideal save for the fact that for the next six hours we were constantly busy helping others and being helped. In that time we moved forward nearly half a mile, past the worst obstructions and were at last free to go. The impression of a storm in the sand hills is not very different from that of a snowstorm; there is the unending stretch of light grey sand, huge drifts and the air filled with flying particles. I hope to spend a day there a little later in the season with anemometer and single register getting an idea of the wind movement and progress of the dunes. The problem of a road has not been satisfactorily solved and the road department would welcome any definite information. The all-American canal to the Imperial Valley is to go through the sand hills also and the Reclamation Service is anxious to secure data on sand movement as a problem for the canal.

Because of the high wind and sand haze pictures taken on the trip were not entirely satisfactory. I am inclosing a few of the best secured.

LEE ON EVAPORATION LOSS FROM WATER SURFACES: MOIST SOILS, WITH SPECIAL REFERENCE TO CONDITIONS IN WESTERN AMERICA

By A. J. HENRY, Meteorologist

[Weather Bureau, Washington, March, 1924]

[Abstract]

The author writes from the standpoint of the practical hydrologist rather than from that of the physicist. After directing attention to the increasing needs for more accurate measures of evaporation he stresses the necessity for the adoption of standard methods of observation, a subject to which further reference will be made later.

Attention is directed to the common failure of many experimenters to closely simulate in the exposure of the experimental pans the natural conditions in the lake or other body of water whose evaporation is sought. Thus floating pans submerged in a large body of water approach rather closely to the actual temperature of the lake or reservoir. In his experience the temperature of the water in floating pans made of light colored metal and kept clean does not vary more than 1° F. or 1.5° F. from that of the surrounding water.

In the matter of vapor pressure, according to the author, there is even greater departure from natural conditions. Too little attention is given to securing a free movement of the air across the pan.

The size of the pan, too, is often given too little consideration.

Concerning lack of standardization of methods of measuring evaporation from water surfaces a list of methods in general use is presented, as in the table below; the table contains in the column next to the last on the right values of the relations of the various rates to that from a 12-foot land pan set in the ground. The data are quoted from Sleight. [1]

TABLE 1.—*Various devices used for measuring evaporation from water surface*

Type	Used by—	Size	Surroundings	Relation to evaporation pan set in ground, as observed by Sleight	
				Mean ratio	Mean ratio
				Per cent	*Per cent*
Piche evaporimenter.	U. S. W. B.		In instrument shelter.		−28.5 to +42.6.
Air pan	U. S. W. B. at Reno and Salton Sea.	Various	Elevated above land or water surface.		
Land pan	U. S. W. B. standard.	4 feet diameter, 10 inches deep.	Above ground.	151.8	−14 to +19.
Land pan or tank.	U. S. D. A. and State experiment stations.	1 foot diameter, 3 feet deep.	Set in ground 2.7 feet.	155.5	−23 to +24.
	do	2 feet diameter, 3 feet deep.	do	129.9	−18 to +17.
	do	3.39 feet diameter, 3 feet deep.	do	120.2	−15 to +19.
	do	6 feet diameter, 3 feet deep.	do	110.2	−11 to +10.
	do	9 feet diameter, 3 feet deep.	do	101.1	−13 to +9.
Floating pan.	U. S. W. B. at Salton Sea.	Various	On raft		
	U. S. G. S. standard.	3 by 3 feet, 1.5 feet deep.	Submerged 1.25 feet.	[1] 108.1	−10 to +11.

[1] Applying correction determined by Sleight as 1.049, to reduce to value comparable with that from circular pans, this is 103 per cent.

A lake or reservoir, considered as a whole, has not as great an opportunity for dissipating its vapor as a pan, since escape is practically limited to the vertical direction. The perimeter of a small pan, however, is relatively large compared to its area since it varies directly with the diameter, while the area varies with the square. The vapor dissipating horizontally from a small pan thus bears an appreciable ratio to the total, while from a large body of water it is practically negligible. The ratio of the rate of wind movement to the distance across a body of water is also an important consideration.

The author holds that temperature, relative humidity, and wind movement are the controlling factors in evaporation from water surfaces.

[1] Sleight, R. B., Evaporation from the surfaces of water and river-bed materials U. S. Dept. Agri., Jour. Agri. Research, Vol. X, No. 5, pp. 209-262.

Quoting again from Sleight it is stated, all other factors being similar, that for each Fahrenheit degree of temperature within the natural range of large bodies of water there occurs a change in the rate of evaporation averaging 6 per cent. The effect of pressure is probably negligible.

The effect of varying specific gravity upon the evaporation rate is presented in some detail, the author quoting from his own studies in the matter as follows:

In order to work out problems arising in the writer's practice, he found it necessary a number of years ago, to undertake an experimental study of the subject. The details and results of this study are herewith presented for the first time. The general program was to evaporate, under exactly similar conditions except as to specific gravity, two samples of water, one distilled and the other a brine with specific gravity 1.11 taken from Owens Lake, Calif., a mineralized lake typical of the Great Basin. The samples were placed in circular flat bottomed pans 4½ inches deep and 12 inches in diameter, filled to the same depth. The pans were left open at the top, immersed for 4 inches of their depth in an electrically heated air bath and placed in a room free from drafts. Constant temperature was maintained in the air bath by means of a thermostat. The successive depth of water in the pans was calculated from the observed weight and specific gravity and known dimensions of the pans. The results of the test are shown in Figure 1. From that diagram it appears that the rate of evaporation from Owens Lake brine decreases as the specific gravity increases, it being about 27 per cent less than distilled water when crusting commenced, at a specific gravity of 1.275. After the crust began to form it was broken up at intervals and the rate was observed to be 75 per cent less than distilled water for a specific gravity of 1.32 and continued to increase with increasing densities. As a practical check on the curve there is available for the period January 1, 1908, to December 31, 1914, detailed data of inflow into Owens Lake and fluctuations of lake level. The average area of exposed water surface during this period was 58,173 acres and the specific gravity of lake water 1.11. The average annual depth of evaporation from the lake surface as determined from the data was 60.8 inches. The observed rate from fresh water at Owens River near Independence for the three years 1908 to 1911 as observed in a floating submerged pan was 67 inches annually. Reducing this by 10 per cent as indicated by the curve there results 60.3 inches for the annual loss from Owens Lake as compared with 60.8 inches as determined above. It is believe that this curve is generally applicable to bodies of highly mineralized water. It should be noted, however, that crusting will probably begin at slightly differing specific gravities, depending upon the chemical composition of the salts in solution.

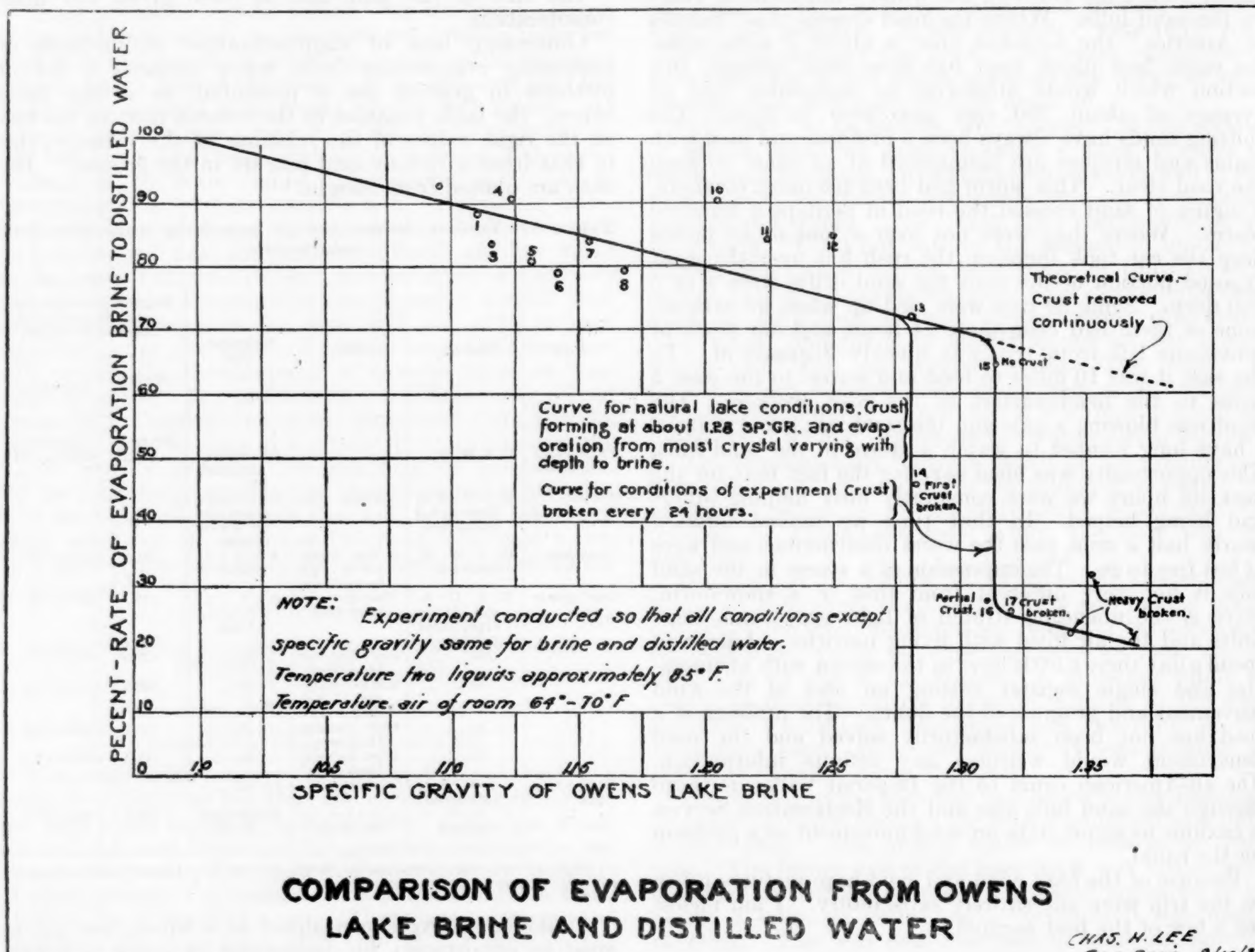


FIG. 1—Comparison of evaporation from Owens Lake brine and distilled water

The practical application of hydrology to problems in western North America involves not only a knowledge of evaporation from a free water surface, but also from capillary films surrounding soil grains, crystals of precipitated alkali salts and snow. The evaporation from moist soil also has three cases which may greatly modify it, viz, transpiration losses from vegetation, surface crusting due to salts precipitated from evaporating soil moisture, and presence of clay in a highly colloidal state resulting from concentrated alkali solutions.

In the hope of stimulating investigation the author outlines the following problems, (1) the evaporation from capillary films; (2) moist soils; (3) the transpiration

from vegetation; and (4) the evaporation from moist crystal deposits and from snow.

His conclusion follows:

In conclusion it is desired to emphasize two points, first, that the study of evaporation should not be confined to free-water surfaces but should be extended to capillary films surrounding soil grains, crystals of alkali salts and snow and in connection with soils should include the process of transpiration; second, that there is greatly needed a study of methods of measuring the various types of evaporation and an authoritative adoption of standards. The subject of evaporation is important not alone in western America but throughout all arid and semi arid regions of the world.

In view of the progress already made in the study of evaporation in its various phases in western America, it is suggested as appropriate and opportune at this time that a committee of the American Meteorological Society be appointed for the purpose of outlining needed investigation and selecting standard methods of observation.

THE COURSE TRAVELED BY WIND AND WEATHER IN A DAY—AN AID IN WEATHER FORECASTING[1]

By DR. C. KASSNER

[Berlin, Germany]

It is known from long experience that not only laymen but also many meteorologists overestimate the velocity of a weather change. In this I do not refer to the fact, for example, that after a rather long period of cold an approaching low-pressure area with warm winds on the front side does not bring a reversal of weather conditions by any means so rapidly as is expected by many who eagerly wish for it. This physical advance will not be considered here, but only the advance of the air masses with wind and weather, or, in other words, the problem of the location after 24 hours of a wind or a low pressure area that is advancing with a given velocity per second or per hour. In this it must naturally be assumed for the sake of simplicity that the path is a straight line. It will, indeed, be a matter of estimation only. But even so it appears to me that the solution of the problem will be rather useful, especially in bringing into lay circles clearer ideas as to the velocity of weather changes.

I proceed with a velocity of 10 meters per second—36 kilometers per hour, 864 kilometers per day of 24 hours. I have chosen this velocity (1) since from this estimation can be made readily for any other velocity, and (2) since this is on an average the velocity with which American depressions move across the Atlantic Ocean toward Europe. Much difficulty was encountered in the selection of the chart to include North America, the Atlantic Ocean, and Europe. I finally decided upon the Mercator projection. Further, in order to meet the requirements for Europe and America I chose two systems of isochronous lines; one with initial position in America, the other with corresponding position in Europe, namely, the meridians of 60° and 0° west longitude, which are marked 0–0. The European system has continuous lines, the American system broken lines. The numbers 1, 2, 3, etc., denote days, that is an air particle or a chosen part of a low pressure area after a day or 24 hours of advance along a parallel, thus from west to east or from east to west, will reach the isochron 1, and in two days the isochron 2, and so on. Of course the beginning may be made with any other isochron. The chosen system of drawing of lines and the different figures do not admit of exchange. We must always take only the lines of one system or those of the other, and not both indiscriminately.

The fact that the isochrons diverge toward the north is naturally the result of curvature of the earth and the projection of a sphere upon a plane surface.[2]

The following small tables may be of value in using the chart:

Velocity equivalents

Meters per second	Kilometers per hour	Kilometers per day
20	72	1,728
15	54	1,296
10	36	864
5	18	432
2.5	9	216

Distance traveled in 1 day in degrees of longitude

Latitude	Length (degrees longitude in kilometers)	Velocity in m. p. s.				
		20	15	10	5	2.5
°		°	°	°	°	°
70	38.18	45.3	33.9	22.6	11.3	5.7
60	55.79	31.0	23.2	15.5	7.7	3.9
50	71.69	24.1	18.1	12.1	6.0	3.0
40	85.38	20.2	15.2	10.1	5.1	2.5
30	96.47	17.9	13.4	9.0	4.5	2.2
20	104.63	16.5	12.4	8.3	4.1	2.1
10	109.63	15.8	11.8	7.9	4.0	2.0
0	111.31	15.5	11.6	7.8	3.9	1.9

Hence at latitude 70° a wind of 20 m. p. s. will traverse an entire quadrant in two days, but at the Equator it will traverse only one-third of that distance; at latitude 70° it would pass along the entire coast of North America, while at the Equator is would just cross South America. It is always useful in making such matters clear to give some geographical measurements, for example:

	Kilometers
Boston–Detroit	1,000
Buffalo–Key West	2,000
Chicago–Salt Lake City	2,000
Baltimore–Salt Lake City	3,000

Up to this point there has been considered only the movement in west-east or east-west direction; the charts contain, however, also the isochrons for the directions north-south and south-north, the broken lines parallel to the parallel circles. Here the velocity of 10 m. p. s. is taken as the basis and the lines are drawn to north and to south of the parallel of 50° N. latitude. In order to avoid confusing figures these lines are not numbered, and to me it appears unnecessary since there are only six to be considered.

If we wish to find with the aid of the chart after what length of time, on an average, a low pressure area whose center lies off Cape Hatteras will arrive on the European coast, we note that the continuous line 8 runs off Hatteras and so the minimum (pressure) is to be expected in the English Channel in about 8 days. An excellent example of this is the cyclone of August, 1873 (Hann, Lehrbuch der Meteorologie, 3 Aufl. S. 610, fig. 80), which lay off Hatteras on the 23d and off Ireland on the 31st; just 8 days were necessary for crossing the ocean. The storm of August 24–September 3, 1883, also shown in the figure mentioned, had a velocity twice

[1] Translated from the German by C. Le Roy Meisinger.

[2] Supervising Forecaster Bowie confirms the fact illustrated by Doctor Kassner's chart, viz, that the northern ends of the major axes of HIGHS and LOWS make greater distance in longitude than their southern ends, so that these major axes incline more and more from north-south to an east-west direction. This action is especially noticeable when troughs of low pressure and ridges of high pressure are about to pass eastward onto the Atlantic from the North American Continent. It is a phenomenon that all students of the weather chart should keep in mind.—*Editor.*

as great from August 28 to 29 (Chicago–Cape Hatteras) and a correspondingly rapid passage to the English coast in only 4 days.

Since weather reports and especially storm reports are now transmitted to ships by wireless my chart can serve in finding the approximate meeting place of ship and storm, especially since 10 m. p. s. is also the speed of many steamships.

THE PHYSICAL AND GEOLOGICAL TRACES OF THE CYCLONE BELT ACROSS NORTH AMERICA[1]

By MARSDEN MANSON

[802 Hobart Building, San Francisco, Calif., December 5, 1924]

Whenever certain portions of the earth for long periods of time have been subjected to meteorological conditions differing from those imposed upon other areas, these different conditions set their marks. These marks, when correctly interpreted, yield lessons of wide import.

It is the object of this essay to show that the path of cyclonic activity of greatest frequency across the narrow continent of North America, from the wide Pacific to the Atlantic, has been subjected to maximum cyclonic activity along this belt, and that this action has persisted well back into geologic history. As the basis of this study, the tracks of LOWS as chartered by the United States Weather Bureau and published in the MONTHLY WEATHER REVIEW are used.

These tracks were studied for two periods, the first, for the 12 months beginning December 1, 1891, and ending November 30, 1892; the second, for the 12 months beginning December 1, 1921, and ending November 30, 1922.

In these studies each LOW which crossed the continent during these years was traced in distinguishing colors and lines from the UNITED STATES MONTHLY WEATHER REVIEW charts by seasons and by months.[2] From these the limits of the tracks of LOWS is outlined upon the accompanying chart; also the summit of the drainage into the Arctic Ocean, Hudson Bay, etc., and into the Gulfs of Mexico and California, etc.

It will be observed that the greater number of these storms move between quite well defined limits, although there are very wide divergent courses taken by some. The most important divergence is that which occurs seasonally on the Pacific coast as the sun moves to its solstitial positions, the summer course being more northerly than that of winter, and during the summer practically no rain falls near the coast south of parallel 42° N. These changes in the paths of LOWS approaching and crossing the coast line, thence into the interior of the continent, establish the wet and dry seasons of California and adjacent territory. Departures from this general winter course give abnormal seasonal precipitation in this State and a reversed abnormality north of this belt.

As the vertical sun approaches the equinoctial position over the Equator, some of the LOWS follow the winter and others the summer track, thus causing the spring and autumn rains of California to be lighter than those of winter, and fixing these seasons as wet or dry according to whether the greater number or intensity of LOWS follow the winter or summer course.

Counteracting pressures of anticyclonic areas.—Opposed to the lessening of pressure attending the passage of a LOW stands the increased pressure due to the passage of a HIGH. The surface of the earth, in isostatic equilibrium, is acted upon by these decreases and increases of pressure.[3] Doubtless the one should in a measure tend to counterbalance the other, if imposed upon the same areas and of equal force. But the Weather Bureau reports above referred to show that the paths of HIGHS are more widely different from those of LOWS. The HIGHS are not accompanied by the denuding effects of rain and snow, as are the LOWS. Hence the latter have unbalanced effects in their favor, and these must have their cumulative results as herein pointed out.

Now, if this great path of north temperate LOWS shall have remained fixed during the Modern Era, and indefinitely into the geologic past, distinctive physical and geologic traces must have resulted from this concentration of denuding activities.

In order to present the ultimate effects which the continued occurrence of a difference in barometric pressure is capable of producing, we must realize that over each square foot subjected to 1 inch less barometric pressure than another a relief of 70.5 pounds obtains. Upon a square mile this amounts to 877,000 tons; a difference of 1 inch is not unusual; indeed, this is not far from the average, and this lessening of pressure acts over areas several hundred miles in diameter. This action, with the accompanying denuding agencies, is repeated every few days now, and could not have been inoperative at any fixed period in geologic time, since one of its causes is the greater amount of solar energy absorbed by the air in the longer oblique path of solar radiation through it about latitude 50°.

This lessening of pressure is equivalent to a lifting force and may seem inconsiderable to the geologist accustomed to consider forces of vaster magnitude; but the great factor time being multiplied into the results gives them mass effects not at first realized. The results of the passage of a single cyclone are physically and geologically insignificant; those passing in a year might be recognized by careful measurements of sedimentations; those passing in several centuries could be so recorded that their results could be observed by successive generations; but when this factor time becomes lengthened into geologic units the effects become physically and geologically traceable.

Physical traces.—The parting of the waters draining into the Arctic Ocean and Hudson Bay, and into the Gulf of Mexico and the Atlantic Ocean, commences on the summit of the Rockies in about 49° N., thence eastwardly in a sinuous line to 75° E. longitude, thence northeastwardly to southwest Labrador in 57° N.

A section of the continent from the mouth of the Mississippi River to that of the Mackenzie crosses this divide near Winnipeg, and both of these great rivers rise on the summit of the great continental plateau.

---

[1] The original studies of this subject were published in the *Transactions of the Technical Society of the Pacific Coast*, July, 1891, under the title, "Physical and Geological Traces of Permanent Cyclone Belts."

This subjects was extended to include the movement of cyclones across the Atlantic Ocean and the continent of Euro-Asia. The present paper is revised and rewritten from the above, and is restricted as indicated in the title.

In April, 1893, the author presented a paper to the Science Association of the University of California, entitled, "The Importance of North Pacific Weather Stations."

The colored maps of the earlier period of cyclone tracks across the continent issued in this paper are utilized herein. *See also Bulletin A*, U. S. Weather Bureau, H. H. C. Dunwoody, Washington, D. C., 1893. *Atlas of Meteorology, Plate 28*, Bartholomew, Edinburgh, Geographical Institute, 1899.

[2] In the tracks of cyclonic areas during the second period, or 30 years later than the first, a larger number of LOWS appear to have developed over the arid and semiarid regions of New Mexico, Arizona, California, and Mexico than in the former period. This is probably due to the establishment of a larger number of observing stations and more intensive studies of the data.

It is probable that the cyclones originating over this area are developments of the modern era of solar climatic control, which, in the views of the writer, did not prevail during geological climates. This subject can not be treated in this essay, but can be found in *The Evolution of Climates*, Manson, 1922.

[3] A convenient instrument for noting the approach and passage of areas of varying air pressures is the seismograph, and it is probable that properly placed seismographs would give warning of the approach of a LOW or of a HIGH prior to the barometer. The observations and researches of Mr. F. Napier Dennison, member of the American Meteorological Society, etc., are notable instances of original work in this field.

Profiles of the continent along the 50th, 35th, and 65th parallels show that the least differences in elevation occur along or near the 50th parallel; and the profiles along the 35th and 65th parallels cross the great valleys at much lower and the great divides at much higher elevations. Moreover, the peaks and passes near parallel 50° N. are lower by from one-half to a full mile than Mount St. Elias, 60¼° N.; Mount McKinley, 63¼° N.; Mount Wrangell, 61½° N.; all of which are still subject to severe glacial action. The peaks and passes to the south are also far higher, as Mount Shasta, 41¾° N., and Mount Whitney, 36½° N. The path of maximum cyclonic activity lies practically along this great east and west watershed, along which maximum denuding activities are concentrated, and from which the denuded materials have been borne to the areas of sedimentation at the mouths of the great rivers. Thus slowly lightening the crustal load at the summit and loading the areas of sedimentation, and tending to cause the former to be an area of slow upheaval and the latter of slow depression.

continental glacier.[5] The geologic evidence that this course of cyclonic activity prevailed during the Ice Age is thus made probable. In the remote Huronian, very extensive glaciation occurred in the interior of Canada and as far south as 46° N. along this path of cyclonic activity. This glaciation was near the center of the continent and remote from the ameliorating influences of warm oceans. Glaciation did not extend from coast to coast, as during the Ice Age, when far colder oceans prevailed.

In the general distribution of the exposure of the rocks of various ages, it is worthy of note that in the continental section from the mouth of the Mississippi to that of the Mackenzie, the oldest rocks are at the heads of these rivers, and the greatest areas of their exposures lie along and adjacent to the zone of maximum cyclonic activity; that the modern rocks are in process of formation at the mouths of these rivers; and that the exposures of rocks of intermediate formations are between these extremes.

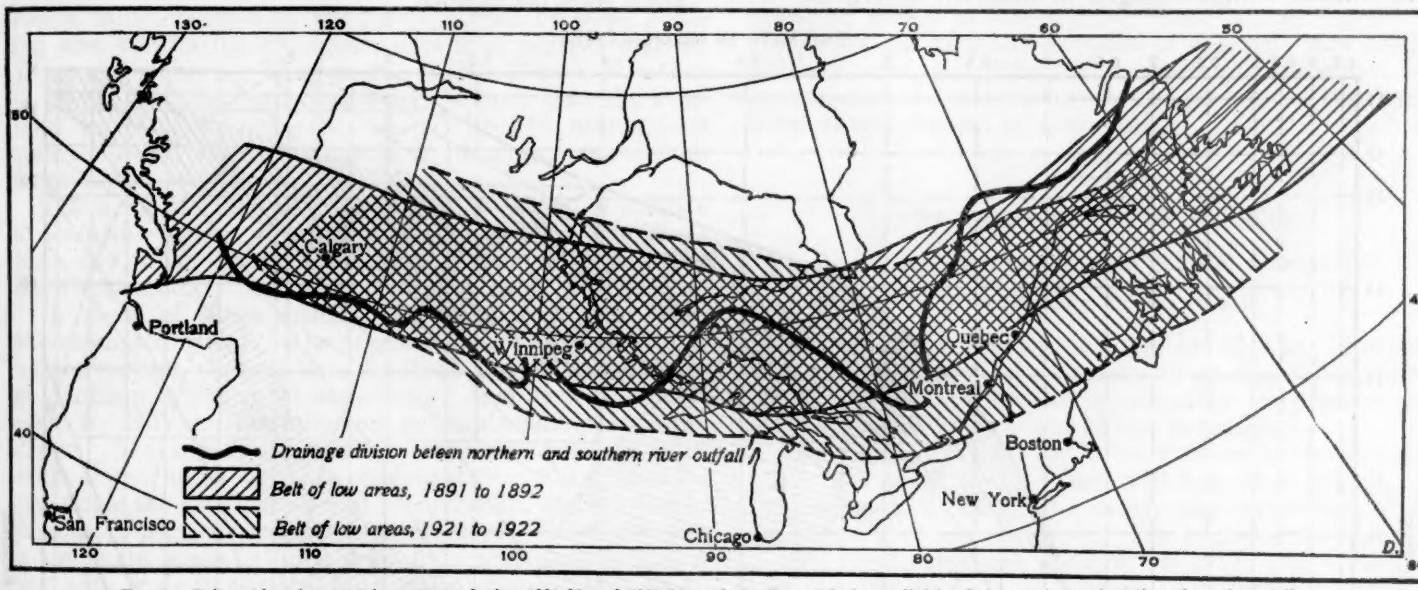


FIG. 1.—Belts of low barometric pressure during 1891–92 and 1921–22, and the line of drainage division between rivers of north and south outfall

Geological traces—The extension of this path into earlier eras.—The geological traces of this concentration of maximum denuding agencies are consequent upon and confirmatory of the evidences of the physical traces just reviewed. The flow of glacial ice and the distribution of till from this zone or path of LOWS is very marked to the South and far less so to the North. In the Mississippi Valley it reaches 38° N. and in that of the Mackenzie 65° N. This greater flow to the South was manifestly caused by the successive partial melting off of the continental glacier during the warm interglacial epochs, and its final melting, all of which were due to exposure to solar energy, to which the southerly slope was most exposed. These meltings and the similarity of the groups of life, which during the warm interglacial epochs occupied the deglaciated areas to those of the Modern Era point to similar control.[4]

Glacial dispersion northerly was thus very much checked, and ice and the materials of till were manifestly drawn southward from the northerly slope of the great

There is no evidence available to the writer which would tend to show that this zone or path of maximum cyclonic activity has not prevailed during geologic time.

CONCLUSIONS

The concentration of cyclonic activities along the course indicated herein has produced three general results:

1. The denudation and upheaval of the crust to its maximum extent along this course and the establishment of the continental drainage line east and west.

[4] See *The Evolution of Climates*, Manson, 1922.

[5] There still persists the view that polar regions were the great sources of glacial dispersion, from which "Arctic conditions swept down from their polar strongholds and invaded the Temperate Zones and even the Tropics." Joly, "The Age of the Earth," p. 32.

Huntington and Visher go into quite an argument to show that the presence of glacial conditions would divert the course of LOWS more to the northward. "Climatic Changes," pp. 115 et seq.

But there does not appear to be sufficient evidence to support these views. The checking of marked glacial flow northward of the crest of the continental glacier tends to negative this last argument; and the presence of ferns, corals, figs, and magnolias, etc., in the Arctic regions during the Permian glaciation of the Tropics does not admit of the former interpretation.

2. This concentration of denuding agencies has worn down the peaks and passes and the plateau regions along this course to the maximum extent, thus causing their slow and constant upheaval, and a corresponding depression of remote areas to which the sediments have been borne.

3. This denudation has also caused maximum exposures of the oldest formations along this path.

The traces of cyclonic activity are thus marked both physically and geologically across the continent.

DETERMINING ATMOSPHERIC CONDITIONS OF COMFORT

By FRANK M. PHILLIPS, Ph. D.

[George Washington University, Washington, D. C., December 7, 1924]

Much is being written in the various scientific journals and books on optimum conditions of heat and humidity for human beings engaged in different activities. The attempt, apparently, is to determine conditions of comfort. The question at stake is not so much what atmospheric conditions are most bracing, nor what give the body most resistance, nor what points on the thermometric and the barometric scales are conducive to health, but what conditions give the least discomfort, which may be one and the same thing as optimum conditions for health.

The New South Wales factory act [1] requires a mean dew point of 62° F., and allows a variation of only 5° either way.

The writer has devised the accompanying chart showing several scales for atmospheric conditions. The horizontal scale is for dry-bulb readings, the vertical one for wet-bulb readings. The solid curves running diagonally across the chart give the relative humidity readings, and the dotted lines give the corresponding dew-point scale. The psychrometric readings can thus be converted into relative humidity and dew-point readings at a glance.

[1] Purdy, J. S.: Lighting and Ventilation of Factories. *The Journal of Industrial Hygiene*, March, 1922, pp. 349-358.

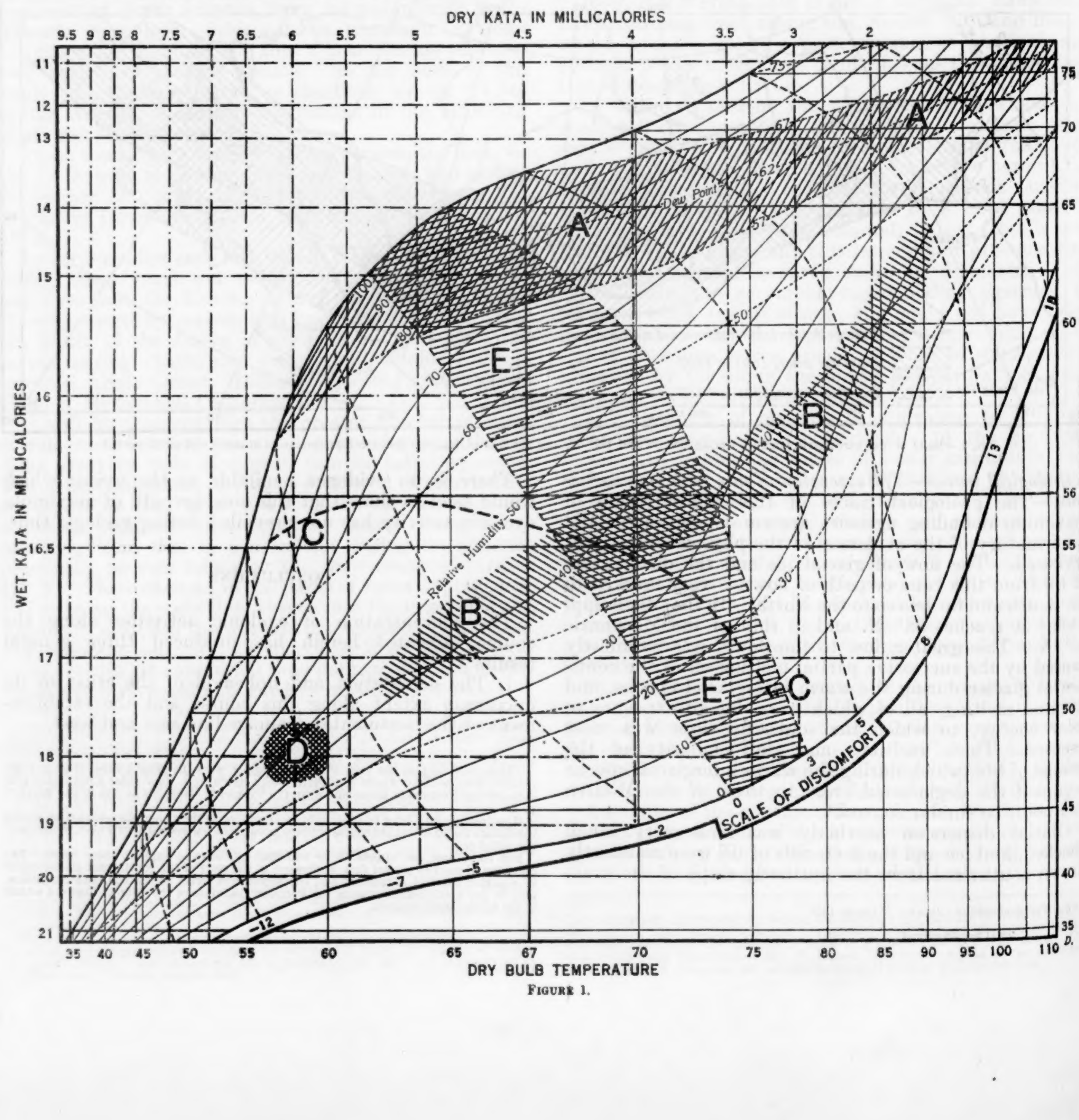


FIGURE 1.

The shaded portion of this chart marked AA shows the comfort area as embodied into the New South Wales law. This law, apparently, does not permit much deviation from these dew-point readings, and does not limit air movement as a function of cooling, although it must be recognized that velocity of air is an important point in furnishing comfort.

It is also evident that the employees require higher temperatures for light sedentary work, than they do for heavy work in which much muscular exertion is necessary.

According to Pierce,[2] the air conditions may vary from 63° F. with a humidity of 40 per cent to 90° F. with a humidity of 25 per cent, and still give comfort in the home. This area is marked BB in the chart. Air movement is again omitted from consideration, but race types are mentioned. These conditions are given as optimum for the home and the hospital, but the author shows the impossibility of hard work in conditions outside of the marked comfort area.

If the comfort area, between certain temperature limits, is determined by the formula used by some heating and ventilating engineers, it is that portion marked CC on the chart. The formula is, $R = 316 - 4$ F.—that is, the conditions most favorable are such that the relative humidity in per cent, should be 316 minus four times the dry bulb reading in F. degrees. Air movement is not considered.

The work of Hill [3] has done more, perhaps, to initiate a scientific study of optimum atmospheric conditions than any other report. A number of interesting articles[4] have appeared.

In most of these articles the principle of the kata thermometer is used. The dry kata cools by radiation and by convection, the wet kata by these and by evaporation in addition. The most satisfactory condition as agreed upon by Hill and his followers in kata readings are here given: For sedentary work a dry kata reading of 6 millicalories and a wet kata reading of 18. For light manual work the readings should be 8 and 25, and for heavy manual work, 10 and 30, respectively. The chart has a wet kata scale in horizontal dots and dashes, and a dry kata scale in vertical dots and dashes. The 6 to 18 area is designated by D.

These instruments, especially the wet kata, are affected by air currents, so that temperature, humidity, and air velocity all function in the results.

The human body, however, is perhaps never a dry kata as far as its surface is concerned, and seldom, if ever, does it become exactly comparable to a wet kata. The use of these instruments, however, has opened up new methods of dealing with questions concerning problems of heating and ventilation.

As one views the accompanying chart, he wonders why these areas, determined as they are to locate comfort areas, should be so far apart. Do the investigators find different answers to the same question? Do the physiologists disagree upon what constitutes comfort? Do racial differences, or geographical locations, cause what is comfort for one set of persons to be discomfort for another set, brought up to live under different climatic conditions?

There remains one more area to notice. Experiments in the laboratories of the Bureau of Mines in Pittsburgh, as shown by investigators from the American Society of Heating and Ventilating Engineers [5] seem to determine comfort lines by making use of bodily sensations of several subjects, and verified by physiological measurements. These lines of equal comfort are shown in the chart by dashed lines. The experiments show the 64° effective temperature line as most comfortable for the light activities in still air. The area is marked EE. Lines for different kinds of work, and for air in motion have yet to be determined.

This area, EE, corresponds only in part with the other four areas determined by different investigators and in different ways. The methods used in determining this last area seem to be purely scientific and accurate, and if pursued to the limit ought to answer some of the questions proposed earlier in this article. Such an experiment involves the use of many subjects of different race stocks, different ages, and different geographical residences, but in time should definitely answer the problem of maximum comfort and degrees of discomfort.

[2] Pierce, W. Dwight. *The Nation's Health*, September, 1922, pp 463-566.

[3] Hill, L.: The Science of Ventilation and Open Air Treatment. *Part II, Medical Research Council, Special Report, Series No. 52*, London, 1920.

[4] Orenstein and Ireland: Experimental Observations upon the Relation of Atmospheric Conditions and the Production of Fatigue in Mine Laborers. *The Journal of Industrial Hygiene*, May, 1922, pp. 30 et seq., followed by a continuation in the June number, pp. 70 et seq.

Vernon, H. M.: Recent Investigations on Atmospheric Conditions in Industry. *The Journal of Industrial Hygiene*, December, 1922, pp. 315–324.

Eadie, Ash, and Angus: Observations of the Reliability of the Comf-thermometer as an Indicator for the Cooling Effect of the Air. *The Journal of Industrial Hygiene*, February, 1923, pp. 441–447.

Hill, Vernon, and Ash: The Kata Thermometer as a Measure of Ventilation. *Proc. Royal Society*, 1922, 93B, 198.

Sayres and Harrington: A Preliminary Study of the Physiological Effects of High Temperatures and High Humidities in Metal Mines, *Engin. and Mining Journal*, 1920, pp. 110, 401.

[5] Houghten and Yagloglou: *Journal of the Society of Heating and Ventilating Engineers*, 1923.

Houghten and Yagloglou: Determination of the Comfort Zone, semiannual meeting of the Society of Heating and Ventilating Engineers, Chicago, May 21–23, 1923, pp. 29–45.

McConnell, Phillips, and Houghten: The Physiological Effects of High Temperatures and Humidities in Still Air. *Public Health Reports*. (In press.)

THE HIGH-ALTITUDE ROCKET

By R. H. GODDARD, Director Physical Laboratories

[Clark University, Worcester, Mass.]

A recent request by the editor of the MONTHLY WEATHER REVIEW for a statement on the rocket development gives a welcome opportunity to present first hand the aims and results of the investigation.

The work at present being carried on is the development of a small model which will have a sufficient vertical range to demonstrate clearly the correctness of the principles that are involved. The propellant consists of liquids, first suggested publicly in 1914, and tested experimentally in 1921, it having been found possible in this way to obtain propulsive force without excessive heating.

After a satisfactory demonstration of this model has been made, the next step, which, it is hoped, will be sufficiently supported financially, is the exploration of the atmosphere in the wide unknown region extending upward from 30 km. to 750 km. (20 to 460 miles). Among the interesting matters to be investigated in this region are whether or not the conclusions from meteoric studies are correct, that the upper limit of the stratosphere is at 60 km. (37 miles), where the temperature rises from −53° C. to 27° C., in a region of ozone, or the conclusions from auroral studies are correct, that the upper limit is at 90 km. (56 miles), where the temperature falls, there being a region above consisting largely of nitrogen at a temperature below 60° A., and extending upward for hundreds of kilometers. In this connection it should be stated that Prof. W. J. Humphreys, of the United States Weather Bureau, has suggested a very simple and clever means of carrying out the most difficult of the measurements, namely, that of temperature.

A further question of interest which may be asked is, To what extent does the moon figure in this rocket investigation? It should be understood, first, that calculations for minimum initial mass of rocket, which take account of both air resistance and gravity, have shown that, for an average velocity of ejection of gases from the rocket of 12,000 ft./sec., an initial mass of rocket of but 40 pounds is necessary for each pound mass given a sufficient velocity (acquired far above the dense part of the atmosphere) to escape from the earth's predominating gravitational attraction. Actual laboratory tests have produced an average speed of ejected gases of closely 8,000 ft./sec., and results from tests *in vacuo* indicate that this corresponds to a speed of 9,700 ft./sec., *in vacuo*. There is every reason to believe, from results so far obtained and from well-established theory, that a sufficiently high velocity can be secured, with a rocket which consists chiefly of propellant material.

The object of the work is, however, much more than the performance of some single spectacular stunt. It is the development of a new method, and although experience has shown that it is hopeless to discuss publicly all the matters which have been studied, both theoretically and experimentally, it is confidently predicted that this method will lead to achievements of the very greatest interest, which can almost certainly be realized in no other way.

New methods are usually slow of development, but it would be well worth while if the means were at hand to make an attack simultaneously upon all the problems connected with this investigation.

BIBLIOGRAPHY OF DR. W. DWIGHT PIERCE'S CONTRIBUTIONS ON METEOROLOGICAL EFFECTS ON LIFE

Dr. W. Dwight Pierce, consulting research director, Banning, Calif., has, during the last two years, published numerous articles dealing with physiological effects of air conditions. In response to a request Doctor Pierce has prepared the following bibliography of his papers, covering meteorological effects on life. Since most of the publications referred to are not usually brought to the attention of meteorologists, the publication of this bibliography should be of value to those studying the biological effects of air conditions.—*C. F. B.*

1. Some factors influencing the development of the boll weevil. Proc. Ent. Soc. Washington, vol. 13, pp. 111–114, discussion 114–117, June 19, 1911.
2. The insect enemies of the cotton boll weevil. W. Dwight Pierce, R. A. Cushman, and C. E. Hood, in U. S. Bureau of Entomology, Bul. 100, pp. 1–99, April 3, 1912. (3 plates, 26 figs.)
3. Mexican cotton boll weevil. W. D. Hunter and W. Dwight Pierce, Senate Document 305, 62d Congress, 2d session, pp. 1–188, 22 plates, 34 figs., April, 1912.
4. Note on temperature control. Proc. Ent. Soc. Washington, vol. 14, p. 87, June 19, 1912.
5. Note on classification of temperatures. Proc. Ent. Soc. Washington, vol. 14, pp. 101, 102, June 19, 1912.
6. A new interpretation of the relationships of temperature and humidity to insect development, Journ. Agric. Research, vol. 5, No. 25, pp. 1183–1191, figs. 1, 2, March 20, 1916. Abstracted in Mo. WEATHER REVIEW, U. S. Dept. of Agric., vol. 47, No. 7, July, 1919, pp. 494–495.
7. The relations of climate and life and their bearings on the study of medical entomology, in Sanitary Entomology (Richard G. Badge, publ., Boston, Mass., edited by W. Dwight Pierce), ch. 6, pp. 97–104, March 6, 1921.

Doctor Pierce says: "These articles trace the beginnings of the philosophy in my lecture on 'The Laws of Nature as Affecting Insect Abundance.'"

8. Air conditioning in hospital sanitation, printed in *The Nation's Health*, vol. 4, No. 7, pp. 444–446, July 15, 1922, and reprinted as "Bringing Climate to the Patient" in *The Modern Hospital*, vol. 19, No. 3, pp. 199–202, September 1, 1922; reviewed in *Literary Digest*, February 10, 1923, p. 27.
9. Air conditioning, longevity, and health, *The Nation's Health*, vol. 4, No. 9, pp. 563–566, September 15, 1922.

There is a series of articles running in *The Western Florist, Seedsman and Nurseryman*, printed in Los Angeles (315 South Broadway) on similar lines as applied to the plant: "Treating the plant as a living being" (April, 1923); "Nursery and greenhouse sanitation" (July, 1923); "Tackling difficult problems" (September, 1923); "Climate and the plant" (December, 1923); "Problems the date growers are trying to solve" (January, 1924).

10. The bearing of climate laws on plant and animal activity, appeared in *The Fruitman* (S. F.) Sept. and Oct., 1923.

WATERSPOUT AND TORNADO WITHIN A TYPHOON AREA

By Prof. GEORGE B. BARBOUR

[Department of Geology, Peking University, Peking, China]

A tornado in north China is sufficiently rare to merit comment, especially if it chooses its path right through the center of the principal summer resort of the entire foreign community north of Shangtung. Peitaiho Beach (39° 48′ N. lat., 119° 30′ E. long.) owes its popularity to the fact that it is the first point along the coast east of Tientsin where bedrock is exposed; all the shore to the west is part of the delta formation of the Bay of Peking upon which Tientsin itself is built.

On the afternoon of August 11, a tornado struck the shore and went inland crossing the foreign settlements at its widest point, seriously damaging all the buildings in its track. It showed the characteristics of those in more southerly latitudes. By good fortune the Italian gunboat *Sebastiano Caboto* was anchored almost in its track, and I am indebted to the careful observations of Capt. G. Viganoni for records he has most generously supplied. Also without the cooperation of Mr. R. D. Goodrich, jr., of Tientsin, I should have been entirely unable to secure other data regarding the occurrence.

Local opinion blames the "extra fifth month" intercalated in 1922 with the abnormal weather experienced since that date. In any case the winter and spring were the mildest in 15 years, the summer less hot and the period of autumn rain showers more than usually protracted. The general weather conditions have been unsettled and the damage by typhoons appears comparatively severe, though this latter is not so easy to estimate.

On August 10 the observatory at Siccawei [Zi-ka-wei] near Shanghai had simultaneous warnings out for two typhoons, one being eventually signaled from latitude 28° N. and longitude 122° E.

At 6 a. m. on the 11th it was reported moving north and described as of extreme violence. The local barometer readings at Peitaiho had stayed at 760 mm. (29.92 inches) until the afternoon of the 10th when the sky became overcast. Heavy rain fell during the latter hours of the night, the wind veered from southwest to northeast with the barometer steady at 759.5 mm. (29.90 inches.)

Soon after 1 p. m. the barometer began to fall, the wind veered sharply to west-southwest and increased to 25 f. p. s. (17 m. p. h.). Rain fell all afternoon with increasing violence, passing into a severe thunderstorm. A few minutes after 4 p. m. a brilliant flash of lightning was accompanied by a particularly loud thunderclap that shook the entire settlement.

At the same time about three-quarters of a mile out to sea, the formation of a whirl could be clearly seen.

The behavior was characteristic. Several observers from the shore speak of noticing two specially heavy clouds rush together and almost at once the formation of a waterspout. When it passed within 20 yards of the *caboto* its height was estimated at 50 feet. Calculations since show that the center of depression moved at about 6 miles an hour toward the northeast. The waterspout only twice linked up as an entire column and of course on striking the shore the characteristics of a whirlwind replaced those of the spout. But the subsequent track on land showed the typical erratic tortuous course, sometimes striking the ground with special violence, elsewhere hopping over a house untouched. The usual freakish

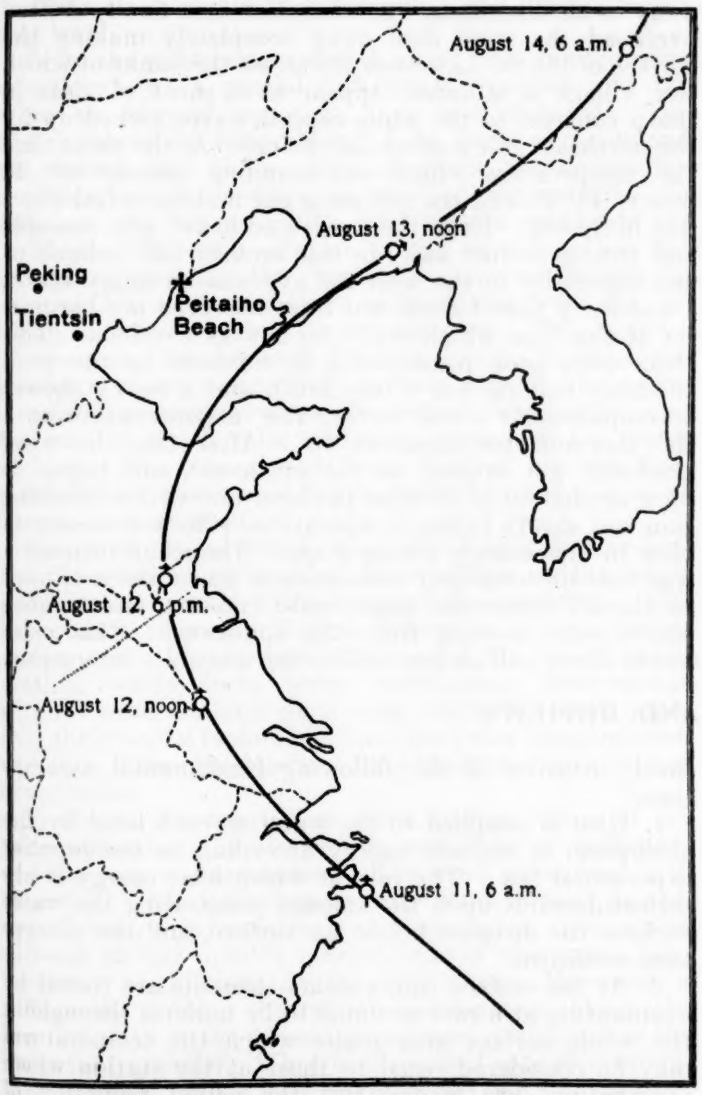


FIG. 1.—Track of Melacosima and China typhoon on Aug. 11-14, 1923

destruction of buildings occurred. Judging by the track left the central zone of the tornado was not much over 150 feet in diameter, its traces were visible at intervals over a distance of 5 miles inland, the last record being where it struck a sand dune one-quarter of a mile west of the military camp near Chinwangtao.

In almost all cases the damage to houses roofed with corrugated iron was much more severe than to tiled buildings. Typical examples are seen in the photographs (not reproduced). In one case a cement block weighing 140 pounds was carried clear over a house 20 feet high. Since the block carried one of the uprights supporting the roof, part of the surface of the latter took the lift, becoming detached in mid-air later.

After the passing of the tornado the wind swung back to northeast and fell to 6 f. p. s. (4.1 m. p. h.), but the barometer continued to fall. As the approach of the typhoon was feared, continuous barometer readings were taken on the *Caboto*. On the afternoon of the next day the pressure fell to 754 mm. (29.68 inches) when the center of the typhoon was located 150 miles to the SSW. By midnight the wind had risen and heavy rain fell with a further drop to 751 mm. (29.57 inches) which continued at a rate of 2 mm. per hour till a minimum of 747 mm. (29.41 inches) was recorded.

The centers of depression that pass north over to the Yellow Sea usually eventually swing NE. and this minimum barometer reading at 6 a. m. (corresponding to a distance of something less than 140 km. for the center of disturbance) indicates that the typhoon had already veered toward Port Arthur. Following this deflection to the NE. early on the 12th, conditions began to improve. By noon of August 13 normal weather was reestablished, at which time the typhoon was signaled from Port Arthur.

The tornado was thus probably a local disturbance produced in advance of the main depression, which was of an unusually persistent and violent character and showed little sign of breaking up even in Manchuria.

COMMENTS

The foregoing article by Professor Barbour reached the Weather Bureau through the instrumentality of Dr. C. F. Brooks, Clark University, Worcester, Mass. It forms a most interesting account of that rare phenomenon of nature— a secondary whirl that forms over the water but later reaches and traverses a land area, being in turn waterspout and tornado. Hann mentions one such whirl [1] and the phenomenon is described in full by Wegener.[2]

Meteorological records in America apparently furnish but one example of this type of secondary whirl. It occurred in southern Florida on September 10, 1919, during the passage of a West India hurricane, the center of which at the time was about 125 miles distant. According to R. W. Gray [3] Weather Bureau official at Miami, Fla., this whirl developed either over the ocean or Biscayne Bay, a shallow body of water at the mouth of the Biscayne River, and in its original form was undoubtedly a waterspout. It is generally known as the Goulds tornado on account of the damage it caused at a small town of that name, located about 20 miles southwest of Miami.—*F. G. T.*

The hurricane itself continued its westward movement across the Gulf of Mexico and entered the Texas coast near Corpus Christi on September 14, immediately losing its identity as a storm center. It was followed on the 15th and 16th by torrential rains in parts of Teaxs and New Mexico and on the 19th a small tornado occurred near the station of Hobbs, in the latter State. The path of this tornado, which was reported and described by Mr. E. H. Byers,[4] cooperative observer, was very narrow, probably at no time more than 100 yards wide, and had a length of about 1 mile. According to Mr. C. E. Linney, Weather Bureau section director for New Mexico, it was the first true tornado to be reported in the State. Since that time, however, two small tornadoes have been observed in New Mexico. While not occurring

[1] Hann's Lehrbuch, 3d ed., p. 726.
[2] A. Wegener, Wind -und Wasserhosen in Europa, pp. 29-34.
[3] MO. WEATHER REV., Sept., 1919, 47: 639.
[4] MO. WEATHER REV., Sept., 1919, 47: 639. Ibid 51: 314.

until after the dissipation of the hurricane it is not improbable that the conditions induced by the latter were favorable for the formation of the tornado.

The typhoon that was in progress when the tornado described by Professor Barbour occurred was, according to the Rev. José Coronas, of the Philippine Weather Bureau, one of eight to visit the Far East in the month of August, 1923. It is known as the *Meiacosima and China Typhoon* and has been described by Father Coronas as follows:

The first part of the track of this typhoon is somewhat uncertain, although it probably formed on August 3 to 4 south of Guam near 145° longitude E. and 10° latitude N., moving northwestward until August 6 and then westward on the 7th and part of the 8th. The center can easily be situated in our weather map of the 8th, 6 a. m., near 130° longitude E., between 18° and 19° latitude N.; and at 6 a. m. of the 9th in about 127° longitude E., between 20° and 21° latitude N. The typhoon was moving then NNW. and so it struck the Meiacosima group of islands about 150 miles east of northern Formosa on the 10th. The station of Ishigakihima reported at 6 a. m. of that day a barometer as low as 722.5 mm. with hurricane winds from the N. From Meiacosima the typhoon inclined northwestward and entered China in the morning of the 11th between 27° and 28° latitude N. Once in China it moved again NNW., gradually recurving to the NE. on the 12th, and traversed Manchuria on the 13th.—EDITOR.

THE EYE OF THE STORM[1]

By DOUGLAS MANNING

[Alexandria Bay, N. Y.]

A rather interesting condition prevailed here yesterday morning, December 6, between 10 and 11:30 o'clock in the forenoon and, in my judgment, it was caused by the immediate passage of a vast low-pressure area centered over this vicinity, or in other words was the "eye of the storm."

At 7 o'clock in the morning when I stepped out of doors it was raining and the wind was blowing almost a whole gale out of the northeast, with the sky covered with dark masses of nimbuslike clouds moving out of the south-southwest and a low scud racing across it from the same direction as the wind or perhaps a point more from the east than the wind was. From then on the wind gradually diminished in force as a patch of blue sky that first appeared in the west approached and which appeared to occupy about a quarter of the sky, and from which the clouds seemed to melt and break away in all directions. As this clear area finally drifted overhead the wind died away completely making the surface of the St. Lawrence River, on the banks of which this village is situated, appear as a sheet of glass in sharp contrast to the white-capped waves kicked up by the northeast gale a short time before. At the same time the temperature which was standing around 36° F. rose to 44° F. and the sun came out making it feel like a day in Spring. Even the cirrus and heavy alto cumulus and stratus melted away in this area but all around us and especially to the west the sky was an angry black. I was sorry that I could not have observed my barometer at this time which read very low at 7 o'clock. This clear space soon passed over us followed by the wind suddenly coming out of the south and a heavy shower accompanied by a still further rise in temperature until the thermometer stood at 50°. After this the wind gradually got around to the southwest and began to blow around 30 to 35 miles per hour and with a drizzling rain and slowly falling temperature, with a tendency to blow in increasingly strong gusts. The cloud formation was that uniform grey seen at such times which is hard to classify otherwise than strato cumulus and nimbus which were moving from the southwest. This calm lasted about half an hour and to me was quite interesting.

[1] Mr. Manning's observations show the prevalence of a central core of calm in an intense extra-tropical cyclone that passed over his station as described. Reference to to the daily weather maps of the Weather Bureau show this cyclone to have had a small diameter and central pressure of 29.15 inches with a fully developed cyclonic circulation.—EDITOR.

NOTES, ABSTRACTS, AND REVIEWS

A METHOD OF COMPUTING EVAPORATION FROM TEMPERATURE GRADIENTS IN LAKES AND RESERVOIRS[1]

By GEO. E. MCEWEN

[Author's abstract]

A satisfactory interpretation of observations on the distribution of temperature, salinity, and other properties of water in the ocean, lakes, or reservoirs demands the mathematical formulation and solution of certain ideal problems. Although "field" observations must underlie the development of appropriate ideal problems, methods similar to those of mathematical physics can be used in dealing logically with such data. Also, as far as practicable, use should be made of well-established principles of physics, based upon laboratory experiments, but the main purpose of it all is to coordinate observations of natural phenomena.

This paper presents certain results of attempting to coordinate the amount of radiant energy absorbed by fresh water, the heat removed by evaporation, the water temperatures at a series of depths, and the time rate of change of temperature at each depth. It does not present any explanation of the mechanism or cause of evaporation. The qualitative physical basis of the theory consists of the following fundamental assumptions:

1. Heat is supplied to the water at each level by the absorption of radiant energy according to the familiar exponential law. The rate at which heat energy is absorbed depends upon the amount penetrating the water surface, the distance below the surface, and the absorption coefficient.

2. At the surface thin volume elements are cooled by evaporation at a rate assumed to be uniform throughout the whole surface area under which the temperatures may be considered equal to those at the station where observations are made. But the actual reduction of temperature of any one element varies—that is, different elements are cooled for different lengths of time, and consequently have different temperatures and specific gravities before beginning their descent. Therefore, the greater the reduction of temperature, or the colder and heavier the elements are, the longer will be the time required to produce the change, and the less frequent will be their descent. Also the number of elements in a given area, having a given temperature reduction will be smaller the greater the amount of the reduction.

3. Each element descends to a depth at which the average (observed) specific gravity is slightly less than that of the descending particle—that is, equilibrium is approached but not completely attained. Consequently

[1] Original paper presented at meeting of American Meteorological Society at Los Angeles, Calif., Sept. 17-19, 1923.

all elements having specific gravities sufficiently greater than the mean at a given level descend through the horizontal plane at that level, and therefore displace lighter water upward through the plane at the same rate. Thus the magnitude of this upward flow of relatively warm and light water is greatest at the surface and decreases continually from the surface downward.

4. The velocity of descent of each element is proportional to the difference between its specific gravity and the average specific gravity of the water at that level.

5. The observed value of any property of the water, physical or chemical (temperature, salinity, CO, etc.), at any depth is the average of the values for all of the water particles or elements, both ascending and descending at that level.

From the assumptions stated above two fundamental equations, one a partial differential equation and the other an intrgral equation, have been deduced. The first involves the temperature of the rising elements and the second that of the rising elements, the descending elements, and the average, or observed temperature. In addition, the times, depths, and certain constants are involved. Although solution of the equations has not proved practicable, the variables entering in can be computed from temperature observations and the relation of specific gravity to temperature. Thus a series of equations, two for each depth, is formed in which the constants stand respectively for the rate of absorption of solar radiation by water, the rate of evaporation, and the rate at which solar radiation penetrates the water surface. The only observations required are the temperatures at a series of depths and their time rates of change at each depth.

Emphasis has commonly been placed upon meteorological observations rather than observations on the water itself in connection with evaporation researches. The importance of meteorological factors in evaporation is undisputed. Hence, determinations of the rate of evaporation, solely from water temperature observations without using meterological data, explicitly must imply that the external factors influence the water temperatures, and thus indirectly determine the computed value of the evaporation.

Preliminary computations have yielded values of the solar radiation, the absorption coefficient of radiation, and the rate of evaporation, all in good agreement with observation. Judging from the experience already gained, any thorough investigation of evaporation from water surfaces should involve observations of the water temperatures at different depths and times. Moreover, a sufficiently refined theoretical development along the line indicated in the present paper may contribute to the important question: What is the actual rate of evaporation of water from a lake or reservoir? (Excerpts from author's abstract.)

A detailed explanation of the above theory, together with typical numerical applications and tables for facilitating the computations, is being prepared for publication.

WIND DRIFT IN RELATION TO GIPSY MOTH CONTROL WORK

During May and June, 1923, an interesting series of observations with small balloons was carried on by the Conservation Commission of the State of New York, Alexander Macdonald, commissioner,[1] in connection with investigations on the spread of the gipsy moth. Previous investigations had shown that wind is a very important factor in the spread of this pest. "Recently hatched caterpillars, less than a quarter of an inch long, are carried by winds when the temperature is 60° F. or higher, and under certain conditions may drift long distances, 20 or possibly 25 miles." Studies were therefore made with a view to determining the probable spread in a given period, the ultimate aim being to secure data on which to base the selection of the most practicable region for a "control zone," in which the destruction of all infestations could be accomplished with least expense and at the same time most effectively. The experiments were conducted under the immediate direction of Dr. E. P. Felt, chief entomologist.

In 1922 the most seriously infested area was that of western Massachusetts, southwestern Vermont, and northwestern Connecticut. Studies of wind frequency were therefore made at selected stations in this region and these showed during the period May 10 to June 8, 1923, that easterly winds occurred at the surface 9 per cent of the time, westerly winds 50 per cent, northerly 47, and southerly 17. The danger of spread into New York State is thus seen to be rather small, so far as surface winds are concerned. Data from the Weather Bureau stations at Albany, Burlington, and Northfield bear out this assumption.

These studies were supplemented by the use of some 7,000 hydrogen-filled toy balloons. The balloons were inflated for a minimum buoyancy, only low altitude drift being desired. Each balloon carried an addressed tag requesting the finder to fill in certain data and then forward the tag by mail. Of the nearly 7,000 balloons released reports were received from 422, about 6 per cent, and 298 of these contained detailed information. A large proportion came down in southern New England, some reaching the eastern and southern coasts and a few crossing the Sound and landing in Long Island. Thus, the general drift was southeastward. About 25 per cent maintained a practically constant direction throughout the flight; a few reached moderate heights and reversed their direction—one actually fell within 15 feet of its starting point, after being in the air more than 6 hours. *Somewhat less than 2 per cent of the total drift was in a westward direction.*

So far as the primary purpose of this investigation is concerned, the conclusion is that the spread of insects westward by wind is likely to be small and that therefore an effective control zone can be established and maintained at comparatively small cost. Meteorologically, the results are of interest as confirming in a general way our ideas of wind frequency in the lower levels, except that the percentage of easterly winds as determined from more extensive data is considerably greater than here shown. The shortness of the period of observation makes inadvisable anything like an unreserved acceptance of the results as generally representative, and, of course, to this extent the conclusion as to the effectiveness of a control zone should be likewise modified.—W. R. G.

[1] Thirteenth Annual Report, Legislative Document (1924), No. 30, pp. 158-169.

NEW ARRANGEMENT OF METEOROLOGICAL WORK IN PORTUGAL

Under date of February 25, 1924, the Director of the Marine Meteorological Service of Portugal, writing from Lisbon, informs this office of a decree of the Portuguese Government which effects a new distribution of the

meteorological activities of that country. This distribution is as follows:

Climatology: Observatorio meteorologico de Lisboa (Faculdade de Sciencias-Lisboa).

Actinometry: Observatorio meteorologico do Porto (Serra do Pilar-Porto).

Terrestrial Magnetism and Seismology: Observatorio meterologico de Coimbra (Cumeada-Coimbra).

Synoptic charts and Forecasting: Serviço meteorologico da Marinha (Lisboa).

Agricultural Meteorology: Serviço meteorologico do Ministerio da Agricultura (Lisboa).

The studies of the high atmosphere and of atmospheric electricity are for the present under the Marine Service but will probably be changed in the reorganization. The Meteorological Service of the Azores will continue in charge of the meteorological work of the islands.

It is suggested that correspondence relating to any of the several fields of work mentioned be addressed directly to the office concerned.—*C. L. M.*

DUST STORMS OF NORTHERN IDAHO AND WESTERN MONTANA

There is a note on the origin of dust fall on page 32, volume 5, of the *Bulletin of the American Meteorological Society*, February, 1924. During my 12 years' residence in Montana and northern Idaho I have witnessed a great many dust storms. These storms, commonly known as "Palousers," have their origin in the desert region of eastern Washington and northeastern Oregon, and are of comparatively frequent occurrence. They are well known and despised by housekeepers in Kalispell, Missoula, Thompson Falls, Libby and all surrounding towns. The dust penetrates into every house and office, making it possible for anyone to write his name on the furniture. When accompanied by rain or snow, the window panes and buildings are besmirched with streaks of red dirt. To have one of these storms happen immediately after painting a house is exasperating. The dust travels over the undulating Palouse region in northern Idaho where the deposits have laid the foundations for one of the richest wheat-producing counties in America. Petersen (see *Science*, January 27, 1923) proved by repeated measurements that this deposit amounted to 2 inches per century. The dust is laid down in the mountains of northern Idaho where it may be seen any day and anywhere during the summer months. Here it no doubt has profoundly influenced the growth and distribution of one of America's most valuable timber trees, the western white pine, for the best growth and development of this species takes place on the deep soils which lie directly in the path of the westerly winds carrying and depositing this dust. One very pronounced dust storm, which many will remember, occurred in March, 1917, when the desert region was dry and bare, but the forested area under cover of snow. At this time a sample of the dust as it had fallen on the snow in northern Idaho was taken, the snow melted, and the amount of dry soil weighed. This showed that the deposit in one single storm amounted to 600 pounds per acre. The dust was observed sticking to the limbs and leaves of trees generally in the Priest River Valley throughout the following summer.

Evidently these storms should be of more than passing interest in that they influence outdoor occupations, farm crops, and timber production.—*J. A. Larsen.*

SOUTH PACIFIC WEATHER REPORTS AND STORM WARNINGS

[Reprinted from Apia (Samoa), *Radio Bulletin, Samoa Times*, January 18, 1924]

South Pacific radio stations are cooperating withthe Apia Observatory in collecting weather reports and broadcasting storm warnings. Suva, Nukualofa, Norfolk Island, Vila, Awanui, and Noumea sent their reports to Apia. Vila exchanges weather reports with Noumea. Norfolk Island passes its report to Suva. Noumea sends its report from Noumea and Vila to Suva. Suva transmits its own and the reports from Vila, Noumea, and Norfolk Island to Apia. Papeete and Nukualofa report direct to Apia.

The message consists of:

1. The station from which the report emanates
2. The barometer.
3. Thermometer—dry.
4. Thermometer—wet.
5. Wind—direction.
6. Wind force by Beaufort scale.
7. Sky and weather in Beaufort letters.

The station broadcasting weather reports makes each report successively. The break sign, dash-dot-dot-dot-dash (bk) separates each report, e. g.—

Apia—30.16–80.78. ENE. 3 BC (bk).

Suva—30.08–79–78 ENE. 5 OCR (bk) and so on, finishing with the time that observations were made, 0330 or 2030 M. M. T. civil (9 a. m. or 4 p. m. Apia time).

These reports are collected by Apia, turned over to Apia Observatory, and broadcasted with storm warnings and Apia's weather report at 2330 G. M. T. civil (noon Apia time) and at 0830 G. M. T. civil (9 p. m. Apia time). When storm warnings are issued Apia broadcasts on 2,000 meters and Suva repeats on 600 meters. If Apia issues a storm warning, Awanui broadcasts the warning immediately after the routine New Zealand weather report and informs the Meteorological Office, Wellington.

BIBLIOGRAPHY

C. FITZHUGH TALMAN, Meteorologist in Charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies.

Bjerknes, V.
Über Wellenbewegung in kompressiblen, schweren Flüssigkeiten. Leipzig. 1916. p. 37–65. 29 cm. (Abhandl. math.-phys. Klasse k. sächs. Gesellsch. der Wissensch. Bd. 35, no. 2.)

Cook, William C.
Studies in the physical ecology of the Noctuidae. St. Paul. n. d. 38 p. diagr. 23 cm. (Univ. of Minn. Agric. exp. sta. Tech. bull., 12, March 1923.) [Discusses meteorological relations of insects.]

Crosby, Irving B.
Earthquake risk in Boston. p. 421–430. map (fold.) 24 cm. (Repr.: Journ. Boston soc. civil eng., v. 10, no. 10, Dec., 1923.)

Debogori-Makrievitch, V. E.
K metodike proizvodstva nabliudenii nad gustotoi stoianiia i massoi sukhogo veshchestva rastenii. [On a method of making observations on density and mass of dry substance of plants.] Poltava. 1915. 38 p. diagr. 25½ cm. (Poltava exper. sta. Dept. of rural-economic meteorolgy.) [Author, title, and text in Russian.]
K voprosu o proizvodstve nabliudenii nad vlazhnostiu pochvy. [On a question concerning observations on the dampness of the ground.] Poltava. 1917. 53 p. illus. 26 cm. (Poltava exper. sta. Dept. rural-economic meteorology.) [Author, title, and text in Russian.]

Eredia, F.
Relazione del segretario della sezione di meteorologia. Venezia. 1923. 9 p. 28 cm. (Estratto Boll. geod. e geof., N. 5.)
Sul clima di Azizia (Tripolitania). Roma. 1923. 19 p. 24 cm. (Boll. di inform. econ., anno 1923, n. 5.)

Finnberg, F. V.
Einige Bestimmungen des Gehaltes der atmosphärischen Niederschläge an Stickstoffverbindungen, ausgeführt in Storkyö (Finnland) 1921–22. 9 p. 23½ cm. (Soc. sci. Fennica. Comm. physico-math. v. 1. 28. Helsingfors. 1923.)

Forni, Giovanni.
Sulla variazione annua del barometro a Milano. Milano. 1922. 15 p. diagr. 33 cm. (Pubb. R. Osserv. astron. di Brera in Milano. N. 58.)

Gabba, L., & Bottino-Barzizza, G.
Sui valori medi delle precipitazioni atmosferiche a Milano. Milano. 1923. 21 p. 33 cm. (Pubb. R. Osserv. astron. di Brera in Milano. N. 60.)

Hellmann, G.
Über die angebliche Zunahme der Blitzgefahr. p. 198–204. diagr. 25½ cm. (Sitzungsb. der k. preuss. Akad. der Wissensch. Sitzung phys.-math. Klasse, no. 10, 22. Feb., 1917.)
Über die Bewegung der Luft in den untersten Schichten der Atmosphäre. pt. 2. p. 174–197. fig. 25 cm. (Sitzungsb. der k. preuss. Akad. der Wissenschaften. Sitzung phys.-math. Klasse, no. 10, 22. Feb., 1917.)

Johansson, Osc. V.
Über einige schnelle und wellenförmige Luftdruckschwankungen. 17 p. 24 cm. (Soc. sci. Fennica Comm. physico-math. v. 1. 42. Helsingfors. 1923.)

Kleinschmidt, E.
Zehnjährige Mittelwerte für Wind, Temperatur und Feuchtigkeit nach den Beobachtungen, Fesselaufstiegen und Pilotmessungen der Drachenstation am Bodensee. Beobachtungen der Drachenstation am Bodensee in den Jahren 1916 und 1917. Der Einfluss des Bodensees auf die Bewölkung und die Nebelbildung. Stuttgart. 1923. p. 31–123. plate (fold.) 29 cm. (Sonderab. Württembergischen Jahrbüchern für Statistik und Landeskunde. Jahrg. 1921/22.)

Knoche, W.
Verteilung des Niederschlagsüberschusses in Chile. 4 p. diagr. 27½ cm. (Mitt. des Deutsch-Chil. Bundes, Concepcion (Chile), H. 1, 3 Jahrg.)

Meares, John Willoughby.
"Experimental development of an automatic integrating 'intensity' rain-gauge without clockwork." London. 1923 29 p. figs. 22 cm. (Inst. civil engin. Selected engineering papers. no. 2.)

Meinzer, Oscar Edward.
Occurrence of ground water in the United States; with a discussion of principles. Washington. 1923. xi, 321 p. illus. plates. maps. 23½ cm. (U. S. Geol. survey, water-supply paper 489.)

Mitchell, W. G. W.
Time and weather by wireless. London. 1923. xii, 125 p. illus. plate. 19 cm.

Pickwell, Gayle.
Tornadoes. The funnel clouds. p. 147–150. illus. 30 cm. [Exc.: Nature mag., Washington. v. 3, March, 1924.]

Rudovits, L.
Ledianoi pokrov Rizhskago zaliva. [Ice cover of the Riga gulf.] Petrograd. 1918. 64 p. diagr. plates. 26 cm. [Author, title and text in Russian.]

Russia. Hydrographic office.
Ledianoi pokrov Finskago zaliva i Alandskago moria. [Ice cover of the Gulf of Finland and the Åland sea.] Petrograd. 1917. 13 p. plates (fold.) 26 cm. [Author, title and text in Russian.]

Schrepfer, Hans.
Blüte- und Erntezeit des Winterroggens in Deutschland nebst einem Anhang über den phänologischen Herbst. Berlin. 1922. 26 p. plates. 26 cm. (Arbeiten der Deutschen Landwirtschafts-Gesellschaft. H. 321.)

Smith, Edward H.
Ice drift in the North Atlantic. Washington. 1924. 1 sheet. charts. 66x96½ cm. (U. S. Hydrog. office. Suppl. pilot chart North Atlantic ocean, March, 1924.)

Smith, W.
Climate of Blackpool and Southport. n. p. n. d. [6 p.] 25½ cm. [Typewritten copy of paper read at Univ. of Liverpool, school of geography. 1924.]

Somerville, Boyle T., *comp.*
Ocean passages for the world. Winds and currents. London. 1923. 585 p. 34½ cm. (Published by order of the Lords commissioners of the Admiralty.)

Sutton, L. J.
Barometric depression of the khamsin type. [Includes] Effect of wind direction on temperature and humidity at Jerusalem. Cairo. 1923. 15 p. plates. 28 cm. (Egypt. Physical dept. Physical dept. paper no. 10.)

Teisserenc de Bort, L[eon] & Rotch, L.
Exposé technique de l'étude de l'atmosphère par sondages aériens. Extrait du mémoire. 23 p. illus. 27 cm. (Trav. scient. de l'Observ. de Trappes, T. 4, 1909.)

Termer, Franz.
Wetterschäden und Landwirtschaft in den Vereinigten Staaten von Amerika. Halle a. Saale. 1923. 78 p. 24 cm. (Studien über Amerika und Spanien. Geogr. Reihe. H. 1.)

Verbetskii, K. L.
Proekt programmy rabot po s. kh. meteorologii. [Plan for the program of work in agricultural meteorology.] Poltava. 1914. iv, 42 p. plate (fold.) 26½ cm. (Otdbl selsko khoziaistvennoi meteorologii pri Poltavskoi opytnoi stantsii.) [Agricultural meteorology of the Poltava experiment station.] [Author, title and text in Russian.]

Westman, J.
Stärke der Sonnenstrahlung im mittelschwedischen Ostseegebiet, Januar 1913–März 1914. Stockholm. 1920. 30 p. 31½ cm. (Kungl. Svenska vetenskapsakad. Hand. Bd. 61. N:o 2.)

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Ace. Los Angeles, Calif. v. 5. February, 1924.
Carpenter, Ford A. Weather conditions in relation to air-routes along the North Pacific coast of America from southern California to northwestern Alaska. p. 5–7.

Aérophile. Paris. 32 année. Janvier 1924.
James, P. Ceux qui disparaissent: G. Eiffel. p. 30. [Obituary. With portrait.]

Akademie der Wissenschaften. Sitzungsberichte. Wien. Abt. IIa. Bd. 132 H. 1 & 2. 1923.
Exner, Felix M. Über die bildung von Windhosen und Zyklonen. p. 1–16.
Oberguggenberger, Viktor. Die durchdringende Strahlung des Bodens und der Atmosphäre in der weiteren Umgebung Innsbrucks. p. 59–68.

American meteorological society. Bulletin. Worcester, Mass. v. 5. February, 1924.
Devereaux, W. C. Some of the river problems the meteorologist can best handle. p. 25–26. (Abstract.]
Hayes, Montrose W. Some of the river problems the meteorologist can best handle. p. 26–29. [Abstract.]
Nunn, Roscoe. Possibilities of a world meteorological foundation. p. 30–31. [Abstract.]
Schneider, Herman. Meteorology in engineering. p. 23. [Abstract.]
Sullivan, W. E. Rainfall intensities and city sewerage in Cincinnati. p. 23–25. [Abstract.]
Visher, Stephen S[argent]. Weather changes in Fiji. p. 22–23. [Abstract.]
Yost, Harold. Adjusting rain insurance policies. p. 17–19.

American society of heating & ventilating engineers. Journal. New York. v. 30. 1924.
Houghten, F. C., & Yagloglou, C. P. Cooling effect on human beings produced by various air velocities. p. 169–184. (Feb.)
Ingels, Margaret. The production and measurement of air dustiness. p. 135–152. (Feb.)
McConnell, W. J., Houghten, F. C., & Yagloglou, C. P. Air motion—high temperatures and various humidities—reactions on human beings. p. 199–223. (March.)

Astronomie. Paris. 38 année. Février 1924.
Antoniadi, E.-M. L'atmosphère de Mars. p. 49–57.

Ciel et terre. Bruxelles. 40 année. Février 1924.
Navarro-Neumann, Emm. Ma. S. Le tremblement de terre du Japon. p. 46–53.

Electrical world. N. Y. v. 83. March 15, 1924.
Creighton, E. E. F. Thunderstorm researches versus no lightning arresters. Comments by an American authority on the recent article by Dr. H. Norinder, describing researches on thunderstorm fields in Sweden and giving conclusions for application to system protective devices. p. 521–523.

Engineering news-record. N. Y. v. 92. Feb. 28, 1924.
Horton, Robert E. Precipitation and runoff near the continental divide. p. 355–358.

France. Académie des sciences. Comptes rendus. Paris. t. 178. 1924.
Gorczynski, Ladislas. Sur la fraction de l'intensité du rayonnement solaire, transmise, pour les diverses longueurs d'onde, par le verre rouge d'Iéna. p. 407–408. (21 janv.)
Stenz, Edward. Mesures de la radiation solaire à Jungfraujoch. p. 513–515. (28 janv.)

France. Office national météorologique. Memorial. Paris. 1 année. no. 7. 1923.
Idrac, P. Étude sur les conditions d'ascendance du vent favorable au vol à voile. p. 1–16.

Geographical journal. London, v. 63. March 1924.
Davidson, C. Distortion of the sea-bed in the Japanese earthquake of 1 September, 1923. p. 241–243.

Heating and ventilating magazine. New York. v. 21. 1924.
O'Connor, G. J. Is our climate changing? p. 53–54. (Feb.)
Bryce, P. H. Studies in house humidifying. p. 43–44. (March.)
Houghten, F. C., Yaglogiou, C. P., & Sayers, R. R. "Effective temperatures" or "equal comfort lines." p. 49–54. (March.)

Hemel en dampkring. Den Haag. 22 jaarg. 1924.
Gallé, P. H. Over schaatsenrijden en klimaat. p. 55–56. (Februari.)
Everdingen, E. van. De winter 1923–1924. p. 89–91. (Maart.)

Ibérica. Tortosa. Año 11. 8 marzo 1924.
Herrera, Emilio. La electricidad atmosférica y la aeronáutica. p. 150–153. [Abstract from Memorial de ingenieros.]

International institute of agriculture. International review of agricultural economics. Rome. new ser. v. 2. January-March, 1924.
F., E. The hail insurance effected by the "Banco de Seguros del Estado." Ley de creación y reglamento general del Banco de Seguros del Estado. p. 139–141.
Hilderbrandsson, M. Insurance of meteorological risks. p. 137–138.
T., F. L. State hail insurance in North Dakota in 1923. p. 138. [Abstr. from Economic world.]

Luftfahrt. Berlin. 28. Jahrg. Februar 1924.
Treibich, Adolf. Einführung in die moderne Wetterkunde. p. 22–24.

Marine observer. London. v. 1. 1924.
Ice in the western North Atlantic. p. 31–34. (March.)
Smith, H. T. Biographical notes of some leaders of marine meteorology. 4. Admiral Robert FitzRoy, C. B., F. R. S. p. 50–52. (April.)

Nature. Paris. 52 année. 1924.
Troller, A. Gustave Eiffel. p. 79–80. (2 fév.) [Obituary. With portrait.]
Vigeron, H. Les aurores boréales. p. 85–87. (9 fév.)

Royal astronomical society of Canada. Journal. Toronto. v. 18. January-February, 1924.
Stewart, R. Meldrum. Dr. Otto Klotz. p. 1–8. [Obituary.]

Royal society of London. Proceedings. London. ser. A. v. 105. January, 1924.
Brunt, D. The dynamics of cyclones and anticyclones regarded as atmospheric vortices. p. 70–80.
Hart, Morris D. On the degradation of acoustical energy. p. 80–96.

Science, New York. v. 59. 1924.
Sanford, Fernando. Air-earth currents and others. p. 194–196. (Feb. 22.)
[Wood, Leonard.] The study of earthquakes in the Philippines. p. 294. (March 28.)

Scientific monthly. New York. v. 18. 1924.
Bretz, J. Harlen. Modern conceptions of earth history. p. 239–256. (March.) ["Climate," p. 246–251.]
Humphreys, W[illiam] J[ackson]. Origin and growth of the weather service of the United States, and Cincinnati's part therein. p. 372–382. (April.)

Seismological society of America. Bulletin. Stanford University, Calif. v. 13. June, 1923.
Macelwane, James B. A study of the relation between the periods of elastic waves and the distance traveled by them, based upon the seismographic records of the California earthquake, January 31, 1922. p. 14–69.

Terrestrial magnetism and atmospheric electricity. Baltimore. v. 28. December, 1923.
Bauer, Louis A. Relations between the diurnal and annual variations of earth currents, terrestrial magnetism and atmospheric electricity. p. 129–140.
Chapman, S., & Whitehead, T. T. On the observations of earth potential-gradients at Ebro. p. 125–128.

SOLAR OBSERVATIONS.

SOLAR AND SKY RADIATION MEASUREMENTS DURING FEBRUARY, 1924

By IRVING F. HAND, Acting in Charge, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1924, **53**: 42.

At Washington, normals of total solar and sky radiation on a horizontal surface in use up to the end of 1923 included values obtained at Central Office from July, 1909, to April, 1912, and Mount Weather, Va., from May, 1913, to October, 1914, inclusive. Normals of solar radiation at normal incidence for the same period included observations taken intermittently at Central Office from June, 1905 to 1913. New normals made up for both the total solar and sky radiation on a horizontal surface and radiation at normal incidence which include only values obtained at the American University since the opening of that station in October, 1914, have been substituted beginning with January, 1924.

From Table 1 it is seen that solar-radiation intensities averaged below normal values for February at all the stations.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged slightly above the normal at Washington and below the normal at Madison, and Lincoln.

Skylight polarization measurements obtained at Washington on three days give a mean of 55 per cent, with a maximum of 65 per cent on the 16th. These are close to average values for February. At Madison no measurements were obtained, as the ground was covered with snow throughout the entire month.

TABLE 1.—*Solar radiation intensities during February, 1924*

[Gram-calories per minute per square centimeter of normal surface]

Date	8 a. m.	Sun's zenith distance									Noon
		78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e
Washington, D. C.											
1924	*mm.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Feb. 2	3.63	0.39	0.43	0.55	0.85		0.86	0.43			3.63
7	2.16	0.55	0.64	0.78	0.95						2.62
9	1.88		1.07	1.19	1.34	1.49	1.20	1.00	0.83	0.69	1.88
11	2.36	0.84	0.96	1.11	1.28	1.48					1.60
12	3.63	0.74	0.84		1.15						3.30
13	2.74		0.67								1.96
15	2.87	0.75	0.86	1.02							2.36
16	1.78		1.06	1.20	1.35	1.48					1.96
20	4.95						1.03	0.66			4.75
21	1.88	0.61	0.72	0.89	1.15	1.45					2.06
28	2.36	0.60	0.72	0.89	1.04	1.21					2.87
Means		**0.64**	**0.80**	**0.95**	**1.14**		**1.03**	**0.70**	**(0.83)**	**(0.69)**	
Departures		**−0.09**	**−0.02**	**−0.04**	**−0.03**		**−0.16**	**−0.27**	**−0.01**	**−0.08**	
Madison, Wis.											
Feb. 11	2.49				1.30						3.99
15	2.87			1.28	1.36						1.32
21	1.19	1.00	1.13	1.22	1.39	1.54					1.45
25	1.37	0.96	1.08	1.17	1.35	1.51	1.33	1.14			2.26
26	1.96						1.22	1.00			2.74
27	2.62	0.83	0.94	1.07	1.21	1.38	1.19	0.94			3.99
Means		**0.93**	**1.05**	**1.18**	**1.32**		**1.25**	**1.03**			
Departures		**−0.01**	**−0.07**	**−0.06**	**−0.05**		**−0.12**	**−0.15**			
Lincoln, Nebr.											
Feb. 2	4.75	0.76			1.33	1.48	1.33	1.20	1.08	0.97	7.87
6	0.86			1.36	1.47	1.59	1.50				1.45
7	1.19		0.96								1.88
11	3.00			1.28	1.44		1.44				3.15
13	4.75						1.21				6.50
21	1.24				1.26						1.88
25	1.37					1.35	1.12	0.94	0.79	0.66	2.74
26	1.52			0.81	1.23	1.38	1.20	1.03	0.89	0.81	3.81
27	2.26			0.82	1.21	1.51	1.33	1.18	1.04	0.97	3.15
28	2.74						1.35	1.12			3.81
29	3.15	0.91	1.03	1.15	1.33	1.53					5.36
Means		**(0.84)**	**(1.00)**	**1.08**	**1.32**		**1.31**	**1.09**	**0.95**	**0.85**	
Departures		**−0.12**	**−0.05**	**−0.12**	**−0.07**		**−0.04**	**−0.08**	**−0.08**	**−0.06**	

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

Week beginning—	Average daily radiation				Average daily departure for the week			Excess or deficiency since first of year		
	Chicago	Washington	Madison	Lincoln	Washington	Madison	Lincoln	Washington	Madison	Lincoln
1924	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Jan. 29	69	201	101	198	+4	−99	−48	+311	−541	+107
Feb. 5	94	193	178	335	−23	−39	+69	+151	−816	+588
12	119	262	197	241	+27	−42	−52	+340	−1,109	+223
19	161	291	296	243	+34	+37	−76	+575	−852	−310

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The following table shows the average pressure for the month at a number of land stations on the coast and islands of the North Atlantic. The readings are for 8 a. m. 75th meridian time and the departures are only approximate, as the normals were taken from the Pilot Chart and are based on Greenwich mean noon observations, or 7 a. m. 75th meridian time.

Station	Average pressure	Departure
	Inches	*Inches*
St. Johns, Newfoundland	29.71	−0.13
Nantucket	30.03	−0.01
Hatteras	30.06	−0.06
Key West	30.11	+0.02
New Orleans	30.14	+0.04
Swan Island	29.96	−0.03
Turks Island	30.13	+0.05
Bermuda	30.07	−0.05
Horta, Azores	30.13	+0.03
Lerwick, Shetland Islands	29.90	+0.17
Valencia, Ireland	30.14	+0.24
London	30.04	+0.04

While the weather over the ocean during the month was not so unfavorable as in January, the number of days on which winds of gale force were reported was, taken as a whole, fully equal to the normal as shown on the Pilot Chart, and somewhat above over the western section of the steamer lanes.

Judging from reports received, fog was unusually rare during the month. The maximum amount occurred in the 5-degree square between the 45th and 50th meridians, where it was observed on 4 days, while comparatively clear weather prevailed over the steamer lanes and off the European coast.

At the time of the Greenwich mean noon observation on the 1st, Newfoundland was surrounded by an area of low pressure, and moderate to strong gales were reported from vessels in the region between the 35th and 50th parallels and 40th and 60th meridians. Heavy winds were also encountered later in the day by vessels in southern waters, as shown by following storm log:

British S. S. *Manchester Spinner:*

Gale began on Jan. 30th, wind E. Lowest barometer 29.93 inches at 5 a. m. on the 1st, wind SSW., 6, in latitude 29° 28′ N., longitude 54° 02′ W. End on the 1st, wind SW. Highest force of wind 8; shifts SSW–SW.

This disturbance apparently moved rapidly northeastward, although it was impossible to locate its position on the 2d, on account of lack of observations. On the 2d a well-developed area of low pressure appeared in the vicinity of Hatteras and strong gales were encountered in the region between the 30th and 35th parallels and the 74th meridian and American coast.

The eastward movement of the LOW was attended by a decided increase in its storm area, which on the 3d extended from the 27th to the 45th parallel, and from the 50th to the 70th meridian.

On the 4th the disturbance was off the east coast of Newfoundland, and increasing in its rate of translation, reaching on the 7th a point near latitude 53° N., longitude 25° W. Storm logs:

British S. S. *Almagro:*

Gale began on the 2d, wind SW. Lowest barometer 29.21 inches at 2 p.m. on the 2d, wind WNW., 10, in latitude 31° 30′ N., longitude 74° W. End on the 3d, wind NNW. Highest force of wind 11; shifts W.-WNW.-NW.

American S. S. *West Caddoa:*

Gale began on the 2d, wind WSW. Lowest barometer 29.70 inches at 10 p.m. on the 2d, wind WNW., 10, in latitude 29° N., longitude 67° 30′ W. End on the 3d, wind NW. Highest force of wind 10, WNW.; shifts W.-WNW.

American S. S. *Balsam:*

Gale began on the 4th wind SE., 7. Lowest barometer 28.74 inches at 8 a.m. on the 4th, wind SSE., 8, in latitude 44° 58′ N., longitude 49° 45′ W. End on the 6th, wind NNW., 6. Highest force of wind 10, N., shifts SE.-WNW.

On the 7th there was another disturbance near Hatteras that moved slowly northeastward, and on the 7th was off the coast of Nova Scotia; this was not accompanied by any very heavy weather, although a few vessels between the 60th meridian and American coast, rendered storm reports.

Maps VIII to XIII cover the period from the 8th to 13th, inclusive, and show the disturbance that on the former date was central near latitude 47° N., longitude 42° W.

On the 9th northerly winds of moderate gale force were encountered off the coast of Florida; these were of anticyclonic origin, as unusually high pressure prevailed along the coast of the southern Atlantic States as well as in the Gulf of Mexico. The disturbance of the 11th and 12th over the western section of the ocean is shown on maps XI and XII, as well as the LOW that on the 11th was central a short distance west of the Azores, and which afterwards joined forces with the northern depression. A large number of storm logs were received from vessels involved in the disturbances mentioned above and reports denoting highest force of wind of from 9 to 11 were not uncommon.

From the 10th to 12th strong winds prevailed within the Tropics as shown by following storm log:

American S. S. *F. H. Hillman:*

Gale began on the 10th, wind NE. Lowest barometer 29.93 inches at 1 p. m. on the 11th, wind ENE., in latitude 13° 31′ N., longitude 74° 54′ W. End of the 12th, wind ENE. Highest force of wind 8; shifts NE.-ENE.

On the 13th and 14th there was a LOW central a short distance south of Newfoundland and vessels in the western section of the steamer lanes, as well as in the vicinity of the Bermudas, reported moderate to strong gales, although in southern waters a number of reports were also received indicating moderate weather.

From the 16th to 21st strong northerly winds were encountered in the vicinity of the Canal Zone, as shown by following storm logs:

American S. S. *S. C. T. Dodd:*

Gale began on the 16th, wind ENE. Lowest barometer 29.87 inches at noon on the 16th, wind ENE., 9, in latitude 11° 03′ N., longitude 78° 53′ W. End on the 18th, wind ENE. Highest force of wind 9; steady ENE.

Dutch S. S. *Moerdijk:*

Gale began on the 19th, wind NE. Lowest barometer 29.85 inches at 8 p. m. on the 19th, wind NE., 7, in latitude 11° 13′ N., longitude 77° 28′ W. End on the 21st, wind E. Highest force of wind 8, NE., shifts NE.-E.

On the 17th St. Johns, Newfoundland, was near the center of a depression, and while no storm logs were received from vessels in the western part of the ocean, the British S. S. *Aral*, on that date, while about 10° east of the Azores, recorded a NNE. wind, force 9, barometer reading 30.16 inches.

By the 18th the northern disturbance was central near latitude 40° N., longitude 42° W., surrounded by a limited area of moderate gales.

On the 20th a LOW in the vicinity of the Virginia Capes was responsible for heavy easterly to southerly winds along the American coast between Charleston and New York, while on the same day a second disturbance was central near latitude 48° N., longitude 37° W.

The western LOW moved northeastward along the coast and on the 22d was over Newfoundland. The second disturbance moved but little from the 20th to the 21st, but on the 22d surrounded the Azores. On the same date Horta recorded a barometer reading of 29.36 inches, while severe gales were reported from the vicinity, as shown by following storm log:

Italian S. S. *Dante Alighieri:*

Gale began on the 22d, wind SE. Lowest barometer 29.27 inches at 6 a. m. on the 22d, wind S., in latitude 37° 44′ N., longitude 25° 44′ W. End on the 23d, wind W.; highest force of wind 10; shifts SE.–S.

On the 23d and 24th moderate conditions were the rule over the entire ocean, with the exception of a few isolated localities where winds of gale force were encountered.

On the 25th a disturbance of limited extent was central near latitude 42° N., longitude 46° W., and strong northwesterly and northerly gales, accompanied by hail and snow, were reported by vessels in the southerly and westerly quadrants, respectively. This LOW apparently moved nearly due north and on the 26th was probably a short distance east of Newfoundland, although it was impossible to plot its position on account of lack of observations.

The daily weather map of the 26th showed a marked depression in the Gulf of Mexico that moved rapidly northeastward, being in the vicinity of Hatteras on the 27th, while winds of gale force swept the American coast from the Virginia Capes to the Bahamas.

On the 27th an area of low pressure was central near latitude 43° N., and longitude 35° W., and moderate gales were reported from the region immediately westward of the Azores.

On the 28th a LOW in the vicinity of the Bermudas was responsible for heavy winds in the southerly and westerly quadrants, and a few vessels in mid-ocean also rendered storm reports.

The British daily weather report for the 29th shows a well-developed depression central near Lerwick, Shetland Islands, and northwesterly winds of gale force were reported by a number of stations in the British Isles, while the few reports received from vessels near the coast indicated moderate weather only.

CYCLONIC DISTURBANCES IN THE SOUTH PACIFIC OCEAN

By ALBERT J. MCCURDY, Jr.

Weather reports received from vessels for February, 1924, indicate that stormy conditions prevailed in the South Pacific Ocean in the first and middle decades of the month.

On February 6 and 7 the American S. S. *W. J. Hanna*, Capt. Norman P. Forbes, proceeding from Talara, Peru, to Bahia Blanca, experienced fresh gales with overcast weather and rough seas. Mr. Vincent R. Cage, observer, states that the lowest pressure observed was 29.70 inches (uncorrected), occurring in the afternoon and night of the 6th, in 41° 21′ S., 77° 16′ W. The wind at this time was west, force 7. Similar conditions continued throughout the 7th.

The British S. S. *City of Naples*, Capt. H. Johnson, proceeding from Sydney to Panama, on February 11, while south of Cook Island, encountered a moderate southerly gale with heavy seas. Mr. R. C. Cooper, observer, states that the lowest pressure observed was 29.76 inches (corrected), occurring at 1 a. m. in 33° 15′ S., 158° 57′ W. The wind at this time was SSE., force 7. The gale ended on the 12th; wind S.

On February 19 winds of gale force were experienced by the British S. S. *Tahiti*, Capt. B. M. Aldwell, Wellington toward Sydney. Mr. J. C. Adams, observer, reports rough northeast seas with heavy rain. At 9 p. m., when in 35½° S., 155½° E., the barometric reading was 29.59 inches (corrected). The wind at this time was northerly, force 6, but later shifted to west and increased to a fresh gale at 1 a. m. on the 20th.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Much stormy weather, with a considerable amount of snowfall, prevailed along the northern trans-Pacific routes during February. Moderate to strong gales occurred daily over some portion of the sea, being most widespread perhaps on the 1st, 2d, 3d, 20th, 25th, 26th, and 28th. The highest force of the wind recorded was 11, whereas in January full hurricane velocities occurred on several occasions.

There is no record at hand of tropical storms in the Far East. In the western coast waters of tropical America the only gales of consequence were such as are typical of the region over and in the neighborhood of the Gulf of Tehuantepec. Here several vessels reported northerly to easterly winds of force 7 to 9 on the 5th, 8th to 10th, 20th and 21st of the month, accompanied by fine, hazy weather, with very little depression of the barometer, and rough seas.

In the Hawaiian region generally brisk trades prevailed. At Honolulu the wind velocities exceeded 25 miles an hour on 10 days, with a maximum velocity of 35 miles from the northeast on the 13th. The prevailing wind was from the east.

The average pressure at Dutch Harbor was 29.53 inches, based on p. m. observations, or 0.03 inch below normal. Such a comparison does not reveal the true pressure conditions at that station, however. Beginning with the 2d the pressure was continuously above normal through the 16th, a period of 15 days wherein the average daily departure was +0.51 inch. From the 17th until the end of the month pressure was continuously below normal, the average daily departure being −0.61 inch. The highest pressure, 30.34 inches, occurred on the 12th and 13th; the lowest, 28.18 inches, on the 25th. Absolute range 2.16 inches. At Midway Island the average pressure (28 days) was 30.08 inches, or 0.08 inch above normal. The highest reading, 30.28 inches, was recorded on the 22d; the lowest, 29.74 inches, on the 17th. At Honolulu the average p. m. pressure was 30.07 inches, or 0.03 inch above normal. The highest reading, 30.23 inches, was recorded on the 25th; the lowest, 29.77 inches, on the 16th.

The alignment of pressure conditions for the ocean as a whole showed the eastern North Pacific HIGH appearing in well-developed form on the first four days of the month. Thereafter until the 20th it was a weaker and more fluctuating area, sometimes cresting over the western portion of the United States or just off the coast, sometimes

ranging in a long narrow band along low latitudes, sometimes receding to the Aleutian regions, and on a few days scarcely in evidence. After the 20th, and until the close of the month it generally dominated the weather along the routes between Hawaii and the United States. Offshoots entered the continent on the 3d, 8th, 23d, and 28th.

In some portion of the area covering the Aleutians and the Gulf of Alaska low pressure continued throughout the month. Up to the 12th the LOW persisted to the eastward of Dutch Harbor, but a disturbance appeared to the westward on the 13th. This settled nearly over the central Aleutians where it remained generally until the 25th, although meanwhile several disturbances evolved from it and moved eastward. After the 25th it fluctuated considerably both eastward and northward, but on the 29th had two centers, one over the Gulf and the other again over Dutch Harbor. Lows from this disturbed region entered the American Continent on the 5th, 7th, 10th, 12th, 13th, 16th, and 27th. That of the 16th gave the Weather Bureau station at North Head, Wash., a maximum wind velocity of 74 miles an hour from the south.

Very low barometric readings were made on several days over Alaska and the northern waters of the Pacific. On the 18th the British S. S. *Canadian Britisher*, in latitude 50° 36′ N., longitude 163° 15′ W., while in the nearly calm center of the great Aleutian cyclone of that date, had a pressure reading of 28.04 inches. This is the lowest recorded reading for the month. On the 22d, in 50° 23′ N., 155° 15′ W., the British S. S. *Empress of Russia* reported a minimum pressure of 28.19 inches. On the 23d the Canadian S. S. *Canadian Scottish* had a reading of 28.21 inches in latitude 51° 11′ N., longitude 157° 46′ W. On the 25th Kodiak had a low reading of 28.10 inches, and on the 26th Bethel, in southwestern Alaska, reported a pressure of 28.06 inches.

Remarkable pressure gradients occurred on the 18th and 26th. Between Eagle, Alaska, and the position of the *Canadian Britisher*, on the 18th, lay a pressure difference of 2.80 inches, the extremes being 28.04 and 30.84. The barometric range between Bethel, Alaska, near 61° N., 161° W., pressure 28.06, and the position of the American S. S. *Lurline*, in 35° N., 146° W., pressure 30.46, on the 26th, was 2.40 inches.

A report from the observer on board the American S. S. *Makaweli*, Capt. Elis R. Johanson, Seattle toward Hilo, is interesting in connection with the cross seas produced by opposing winds of force no higher than 4. He says:

> Saturday, February 23, 2:45 p. m., apparent position 33° 23′ N., 143° 42′ W. Heavy rain showers from SW. and NW. causing confused sea, as both winds were fighting against each other and raising waves like starting points of small waterspouts. Observed by master and second officer and commented on as a remarkable phenomenon, as the ship could actually feel the two winds, and the effects of both meeting were plainly visible over parts of the ocean.

Severe gales swept a considerable portion of the western half of the sea on the 1st to the 4th, and more moderate gales occurred on the 1st to the 3d between the 30th and 40th parallels from the 180th meridian eastward to the American coast. The storm conditions were most intense on the 1st and 3d.

On the 1st the American S. S. *Dilworth* was eastward bound in a southeasterly to southwesterly gale, force 11, lowest pressure 28.88, in 38° 14′ N., 171° 38′ E. On the 3d the American S. S. *China Arrow*, eastward bound, caught the extreme violence of the great cyclone in latitude 40° 15′ N., longitude 161° 46′ E. The lowest noted pressure was 28.45 inches. The observer reported, "Heavy mist and rain, storm to hurricane, mountainous seas." The Japanese S. S. *Horaisan Maru*, Kobe toward San Francisco, encountered the lowest pressure, 28.77 inches, highest wind force 11 SSW., in 39° 55′ N., 165° 34′ E. During the worst of the storm the "ship kept her head on SW'ard. Several other vessels in the vicinity experienced gales of force 10, among them the American S. S. *Bearport*, wind west, lowest pressure 28.50, in 44° 35′ N., 158° 11′ E., and the British S. S. *Canadian Freighter*, wind ESE., lowest pressure 29.13, in 46° N., 172° 30′ E.

On February 6 a cyclone left the northern China coast. By the 8th, with increased energy, the storm was crossing northern Japan, where a west wind, force 10, was observed at Nemuro. So far as our reports indicate, this storm diminished in severity shortly after entering upon the sea. The only report concerning it at this time is from the British S. S. *Shabonee*. This vessel during the 8th had moderate SSW. to NW. gales between 36° N., 144° E. and 40° N., 150° E., with lowest pressure 29.60 inches.

On the same date, in 44° 36′ N., 143° 30′ W., the American S. S. *Jadden*, westward bound, experienced a southwest gale, force 10, pressure 29.39 inches.

The next important cyclone to issue from the Asiatic continent was that of the 11th and 12th. On the first date a northwesterly gale, force 9, pressure 29.63, was noted by the American S. S. *William Campion*, in 34° 53′ N., 139° 42′ E. The storm moved into the ocean on the 12th and 13th, and by the 18th had added considerable energy to the Aleutian cyclone then central southeast of Dutch Harbor. Meanwhile, to the westward of the 180th meridian, rough weather and snow squalls occurred frequently, with occasional wind velocities attaining a force of 10.

Pressure remained low over northern Japan until the 28th, when anticyclonic conditions overspread the entire archipelago.

During the last decade of the month the days with severest weather over east longitudes were the 20th, 24th, 25th, 28th, and 29th.

On the 20th vessels as follows reported gales of force 10: American S. S. *Steel Traveler*, wind SW., pressure 30.02, in 31° 30′ N., 131° 02′ E.; American S. S. *Independence*, wind SW., pressure 29.49, in 32° 12′ N., 151° 30′ E.; American S. S. *West Ivan*, wind N., pressure 29.48, in 32° 25′ N., 154° E.

On the 24th the American S. S. *President Madison* ran into a westerly gale, force 10, pressure 29.31, in 42° 05′ N., 152° 32′ E.

On the 25th the American S. S. *Java Arrow*, eastward bound, fell into a westerly gale, force 10, pressure 29.36, in 39° 56′ N., 166° 20′ E.

During the 23d to 26th the American S. S. *Stockton*, Manila toward Portland, Oreg., experienced almost constant gales, mostly from the west and northwest, between 39° N., 155° E. and 46° N., 172° E. Continuous precipitation occurred during this period, mostly as rain, but with frequent snow squalls. The highest wind force was 9, lowest pressure 28.87, in 44° 05′ N., 165° 20′ E., on the 25th.

On the 28th and 29th the last Japanese disturbance of the month swept with increasing power upon the Pacific. Report is at hand from only one vessel in this area. The American S. S. *West Kader*, westward bound, while in 42° 45′ N., 152° 30′ E., passed through the extreme violence of this cyclone, breasting a westerly gale, force 11, minimum pressure 29.26 inches.

In west longitudes, during the last decade, the Aleutian cyclone also was productive of strong wintry gales, the greatest violence of which occurred on the same days as to the westward of the 180th meridian.

On the 19th and 20th the American S. S. *Carriso*, Manila toward San Francisco, near 43° 40′ N., 146° 30′ W., encountered whole westerly gales, lowest pressure 28.69, late on the 19th. On the 20th the British S. S. *Tyndareus*, in 50° 06′ N., 141° 46′ W., experienced its lowest pressure, 28.71 inches, in the same storm. Quoting from the observer:

> 3 a. m., wind veered to ESE. 7. 4 a. m. SE. 8, lowest barometer. 5 a. m., veered to SSE. 8. 6 a. m., veered to S. 8. 8 a. m., wind increased to force 10. Noon, wind veered to SSW. 8. 8 p. m., wind and sea decreasing.

On the 24th and 25th, the storm center was very near Dutch Harbor, but the cyclone was of great dimensions. The Canadian S. S. *Canadian Scottish*, in 53° 57′ N., 139° 44′ W., experienced the highest wind force, 11 from the southwest. The American S. S. *President Jackson*, in 50° 55′ N., 156° 30′ W., encountered a south to southwest gale, force 11, lowest pressure 28.12 inches.

On the last two days of the month, with the cyclone central over the northern Gulf of Alaska, the American S. S. *Eldridge* experienced whole gales to storm winds from westerly directions, the lowest pressure noted being 28.68, in 49° 42′ N., 153° 20′ W., on the 28th.

Fog occurred along the northern and middle steamship routes on several days, but was not so frequent as during January, except along the American coast between 25° and 50° N. Here it was particularly frequent between 30° and 40° N., where it was observed on 30 or more per cent of the days.

From the standpoint of the seaman the rough weather of February resulted principally in delays between ports, many vessels being compelled to slow engines for hours at a time in the face of enormous or greatly confused seas.

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

By ALFRED J. HENRY

A dry month everywhere, except locally in the State of Washington, in the Missouri Valley, the Gulf States and the Lake region. Dry weather continued in Oregon and California.

Temperature was above the normal in the Northwest and below in the Southeast, the dividing line between the two areas running northeast-southwest from west Texas to the Lake region. The usual details follow.

CYCLONES AND ANTICYCLONES

By W. P. DAY

Low-pressure areas were about normal in number, but included a large proportion of secondary developments over the South and Southwest. There were an unusual number of large and sluggish high-pressure areas. These HIGHS occupied the northern interior districts for days at a time and probably prevented the normal eastward drift of the LOWS and favored the development of secondaries over southern districts. These southern LOWS were also affected and showed numerous abnormal movements. In other words, there was a more or less continuous outflow of cold air from the northern interior with somewhat abortive attempts on the part of the warm air to pierce this front, at least over the continental areas.

FREE-AIR SUMMARY

By L. T. SAMUELS, Meteorologist

There are shown in Table 1, the monthly mean temperatures, relative humidities and vapor pressures together with the departures from normal and in Table 2, the resultant wind directions and velocities and the normals. The large positive temperature departures at all levels at Ellendale are conspicuous while practically the opposite condition is found at Due West. The very excellent agreement between the temperature departures found for the various kite stations and those shown in Climatological Chart III is of particular interest in that it indicates the close approximation to the true average monthly temperatures as determined from the daily maxima and minima of surface observations and those found at the average time of kite flights.

The resultant wind directions at Drexel and Ellendale showed the largest deviation from the normals, there being a very pronounced north component in the monthly means. This, it may appear, is somewhat in conflict with the fact that these two stations showed the largest positive temperature departures, but it will be observed that the resultant velocities for the month at these stations were considerably less than normal. It is further probable that in a number of cases the northerly winds at these stations were not necessarily relatively cold winds but as was indicated in the free-air summary for January, 1924, may have followed a curved path and originated over a relatively warm region.

As a rule a well-developed LOW is accompanied, not only by considerable cloudiness, but at least in certain quadrants by more or less widespread precipitation as well, thereby making it impracticable to secure within its confines good kite or pilot-balloon observations. On the morning of the 3d, however, there appeared a deep LOW central over the lower Missouri Valley which in the second respect differed from the average. For this reason it seems advisable to relate in some detail the characteristics of the upper atmosphere as shown by aerological observations during the eastward advance of this storm. Its movement across the country was conspicuously slow, the center being over the lower Lakes three days later. The precipitation area increased rapidly, however, after the 3d, but fortunately good kite observations were obtained during the most of this period, some of these being made during snow flurries. The times of these observations were approximately the same as indicated by the morning weather charts so that reference to the latter is suggested in order to locate the position of any particular station relative to the storm center.

Attention is first invited to the "flat map" of the 2d with respect to both pressure and temperature gradients (not reproduced). The free-air temperatures on this day exhibited the same characteristics, there being practically no temperature difference between Drexel and Groesbeck from 1,000 to 4,000 m. It seems probable that this fact played a part in the rapid development of thd LOW as found the next morning. On the next day (3d) all of the kite stations except Due West were within the boundaries of this storm and fortunately all stations

except Broken Arrow obtained morning kite observations. All altitudes referred to are above sea level, unless otherwise stated.

February 3, 1924, altitude (meters above sea-level)

Station	Surface	1,000	2,000	3,000	4,000	5,000
Ellendale, N. Dak.:						
Wind direction	N.	NNE.	NNE.	NNE.		
Temperature (°C.)	-7	-10	-6	-10		
Relative humidity (per cent)	92	94	48	38		
Drexel, Nebr.:						
Wind direction	NE.	ENE.	E.			
Temperature (°C.)	1	7	7			
Relative humidity (per cent)	98	70	37			
Groesbeck, Tex.:						
Wind direction	S.	WSW.	WSW.			
Temperature (°C.)	13	16	10			
Relative humidity (per cent)	83	52	33			
Royal Center, Ind.:						
Wind direction	E.	SSW.	WSW.	SW.	SW.	
Temperature (°C.)	1	10	4	-4	-11	
Relative humidity (per cent)	92	53	58	74	88	
Due West, S. C.:						
Wind direction	SW.	W.	W.	WSW.	WSW.	WSW.
Temperature (°C.)	3	8	4	0	-7	-14
Relative humidity (per cent)	88	68	69	58	50	48

Ellendale, situated in the NW. quadrant; wind NNE. to at least 3,000 m.; adiabatic rate for dry air from surface to 870 m., sharp inversion to 1,460 m., isothermal to 2, 100 m., above which the average winter lapse rate for that elevation prevailed to 3,000 m.; surface relative humidity high, altitude of St base about 850 m., upper limit of clouds at base of inversion; light snow during flight.

Drexel, situated just north of the region of lowest pressure; wind NE., veering gradually, becoming SW. at 4,500 m.; general temperature inversion from surface to 1,650 m., then a decrease to 2,700 m. at slightly less than the adiabatic rate for dry air; light fog at surface, depening by end of flight as the temperature decreased with altitude and the inversion became elevated, the fog then reaching to the base of the inversion.

Groesbeck, situated in the extreme S. portion of the LOW; surface wind S., WSW. at 500 to 2,500 m.; vertical temperature gradient very similar to that at Drexel with inversion extending to 1,200 m.; during the flight the WSW. wind changed to SW., coincident with a drop in temperature. This resulted in a nearly adiabatic rate from the surface to 520 m. and in a thin St cloud with its top at the base of the inversion.

Royal Center, situated in the E. portion; surface wind E., rapidly veering to S. at 500 m. and SW. from 1,500 to 4,000 m.; temperature inversion from surface to 1,000 m., then decreased at nearly the adiabatic rate for dry air to 4,000 m.; surface relative humidity high but decreased rapidly with altitude to 50 per cent until just below level of A. Cu. base at 4,000 m.

February 4, 1924, altitude (meters above sea level)

Station	Surface	1,000	2,000	3,000	4,000
Ellendale, N. Dak.:					
Wind direction	N.	NNE.	NNE.	NNE.	
Temperature (°C.)	−21	−21	−16	−18	
Relative humidity (per cent)	84	77	35	26	
Drexel, Nebr.:					
Wind direction	N.	N.	N.		
Temperature (°C.)	−9	−11	−11		
Relative humidity (per cent)	97	91	92		
Groesbeck, Tex.:					
Wind direction	NW.	NW.			
Temperature (°C.)	2	−5			
Relative humidity (per cent)	63	69			
Due West, S. C.:					
Wind direction	SSE.	SSW.	SSW.	SW.	SW.
Temperature (°C.)	6	6	3	−3	−9
Relative humidity (per cent)	90	91	64	60	62

On the 4th the storm center was over southern Missouri, snow having fallen throughout the NW. quadrant with thunderstorms general around the center and a portion of the south quadrant. On this morning all kite stations except Ellendale were within its influence and morning kite flights were obtained at all of these except Broken Arrow. Following are some characteristics shown by these observations:

Drexel, situated in the NW. quadrant; wind N., surface to 1,900 m., the limit of the observation; temperature decreased at practically adiabatic rate for dry air from surface to 870 m., then practically isothermal to 1,900 m.; light snow during flight; surface relative humidity above 90 per cent increasing to 100 per cent at all upper levels; St base about 800 m.

Groesbeck, situated in the SW. quadrant; wind NW. surface and aloft; temperature decreased at practically adiabatic rate for dry air from surface to 1,500 m., then sharp inversion to 1,800 m., the upper limit of the observation; surface relative humidity 60 per cent and slightly higher aloft; kites did not reach St. Cu.

Due West, situated in the E. quadrant; surface wind SSE., veering aloft to SW. from 3,000 to 4,000 m.; sharp temperature inversion from surface to 570 m., then nearly adiabatic rate for dry air to 1,420 m., followed by a small inversion, above which, the average winter lapse rate for those levels occurred; surface relative humidity from 90 per cent to 80 per cent, decreasing to 60 per cent at highest level (4,000 m.).

February 5, 1924, altitude (meters above sea level)

Station	Surface	1,000	2,000	3,000	4,000
Ellendale, N. Dak.:					
Wind direction	NNW.	NE.	NE.	NNE.	N.
Temperature (°C.)	−24	−16	−13	−16	−20
Relatively humidity (per cent)	80	55	34	30	28
Drexel, Nebr.:					
Wind direction	N.	NNE.	NNE.	NNE.	
Temperature (°C.)	−19	−14	−12	−17	
Relatively humidity (per cent)	100	73	40	66	
Broken Arrow, Okla.:					
Wind direction	NNW.	NNW.	NNW.		
Temperature (°C.)	−11	−15	−14		
Relative humidity (per cent)	79	85	99		
Groesbeck, Tex.:					
Wind direction	NW.	WNW.	WNW.		
Temperature (°C.)	−2	−10	−12		
Relative humidity (per cent)	56	59	49		
Royal Center, Ind.:					
Wind direction	ESE.	SW.	SW.		
Temperature (°C.)	0	0	−7		
Relative humidity (per cent)	98	78	92		
Due West, S. C.:					
Wind direction	SW.	SW.	SSW.		
Temperature (°C.)	11	4	1		
Relative humidity (per cent)	87	82	61		

On the 5th the storm center was over Indiana and all kite stations except Ellendale were again within its immediate limits. On this day it was found that practically no difference existed between the free-air temperatures from Ellendale to Groesbeck, from 1,500 m. to 3,000 m., the upper limit of the observations. Following are the characteristics shown at the individual stations on the morning of this date.

Drexel, situated in the W. portion; surface wind N. shifting rapidly aloft to NNE., remaining so to top level; temperature decreased at the adiabatic rate for dry air from surface to 800 m., then a sharp inversion to 1,000 m., followed by a practically isothermal layer to at least 3,000 m.; surface relative humidity nearly 100 per cent, decreasing to 40 per cent at 2,000 m., increasing again to 65 per cent at the top.

Broken Arrow, situated in the SW. quadrant, wind NNW. at surface, NW. at highest level (2,600 m.); temperature decreased at the adiabatic rate for dry air

from surface to 640 m., then practically isothermal to the highest level as at Drexel; surface relative humidity 80 per cent, increasing aloft to St Cu base at 1,100 m. and remaining 100 per cent to top level; light snow during flight.

Groesbeck, situated in the SW. quadrant; surface wind NW., WNW. at all levels above to top of observation (2,600 m.); temperature decreased at the adiabatic rate for dry air from surface to 650 m., then at a lesser rate to 1,700 m., followed by a practically isothermal layer as at the former stations, to the highest level; surface relative humidity 50 per cent, with little change to the highest altitude.

Royal Center, situated just north of the storm center; wind ESE. to SE. at surface, rapidly veering aloft to SW. from 870 m. to the highest level (2,200 m.); temperature practically isothermal from surface to 870 m., then nearly the adiabatic rate for dry air; relative humidity 100 per cent at surface and all levels; base of St Cu about 600 m.; light snow during flight.

Due West, situated in the SE. quadrant, wind SW. at surface and SSW. aloft; temperature decreased at the adiabatic rate for dry air from surface to 1,500 m., then a shallow inversion, above which a small lapse rate was found; relative humidity at surface from 87 per cent to 64 per cent, increasing aloft to St base at 1,000 m., top limit of St at base of inversion at 1,500 m.; light rain just preceding flight.

February 6, 1924, altitude (meters above sea-level)

Station	Surface	1,000	2,000
Royal Center, Ind.:			
Wind direction	SW.	SSW.	WNW.
Temperature (°C.)	−10	−14	−15
Relative humidity (per cent)	100	100	100
Due West, S. C.:			
Wind direction	W.	WSW.	SW.
Temperature (°C.)	−1	−8	−10
Relative humidity (per cent)	58		

On the 6th the storm was centered over Lake Huron while Royal Center and Due West remained within its boundaries, and kite flights from these two stations showed the following characteristics.

Royal Center, situated in the SW. quadrant; surface wind SW., veering to WNW. at 2,200 m., the highest level reached; temperature lapse rate nearly adiabatic for dry air from surface to 1,150 m., then a sharp inversion of 100 m. depth, then practically isothermal to the top level; relative humidity practically 100 per cent surface and aloft; Nb. base about 1,000 m. and extending in depth at least to highest level. During flight when temperature lapse rate off surface had increased the cloud base lowered to 650 m.; snowing during flight.

Due West, situated in the S. quadrant; wind W. at surface and WSW. to SW. aloft to highest level (2,800 m.); temperature decreased at nearly the adiabatic rate for dry air from surface to 1,870 m., above which was found a sharp inversion to 2,100 m.; then the normal lapse rate; surface relative humidity 50 per cent; St. base about 1,600 m., depth of clouds unknown as no free-air humidity record was obtained; light snow during flight.

TABLE 1.—*Free-air temperatures, relative humidities and vapor pressures during February, 1924*

TEMPERATURE (° C.)

Altitude m. s. l. (m.)	Broken Arrow, Okla. (233 m.) Mean	Departure from 6-yr. mean	Drexel, Nebr. (396 m.) Mean	Departure from 9-yr. mean	Due West, S. C. (217 m.) Mean	Departure from 3-yr. mean	Ellendale, N. Dak. (444 m.) Mean	Departure from 7-yr. mean	Groesbeck, Tex. (141 m.) Mean	Departure from 6-yr. mean	Royal Center, Ind. (225 m.) Mean	Departure from 6-yr. mean
Surface	4.8	−0.2	−1.9	+2.2	5.9	−2.5	−6.9	+3.6	8.0	−1.8	−2.6	−0.3
250	4.8	−0.1			5.6	−2.6			7.9	−1.6	−2.8	−0.3
500	4.4	+0.9	−1.9	+2.6	4.4	−2.5	−6.8	+3.7	7.1	−1.4	−4.7	−0.3
750	3.6	+1.1	−1.9	+3.0	3.4	−2.5	−6.4	+3.7	6.5	−1.6	−5.1	0.0
1,000	3.0	+0.9	−1.5	+2.9	2.9	−2.3	−5.4	+4.1	6.5	−1.3	−5.1	+0.3
1,250	2.5	+0.7	−1.1	+2.7	1.8	−2.5	−5.1	+3.8	6.0	−1.2	−5.5	+0.5
1,500	2.0	+0.9	−1.4	+2.5	0.6	−2.8	−5.2	+3.5	5.2	−1.3	−6.0	+0.4
2,000	0.8	+1.0	−2.8	+2.2	−0.1	−2.0	−6.9	+3.0	3.2	−1.5	−7.0	+0.5
2,500	−1.2	+1.2	−4.8	+2.3	−2.5	−1.9	−9.0	+2.9	0.6	−1.9	−9.4	−0.3
3,000	−3.7	+1.2	−7.2	+2.4	−5.4	−2.5	−11.1	+3.4	−1.2	−1.4	−13.0	−1.7
3,500	−6.2	+1.1	−9.8	+2.5	−8.4	−2.8	−13.3	+3.8	−3.8	−1.6	−16.8	−2.9
4,000	−8.7	+1.2	−12.8	+2.3	−11.8	−2.8	−15.5	+4.1	−6.3	−1.7	−20.9	−4.0
4,500	−11.7	+1.2	−16.0	+2.3	−15.2	−2.8	−17.5	+4.8	−9.5	−2.5		
5,000	−14.9	+1.2	−19.3	+2.7	−18.2	−2.8	−20.3	+4.9	−12.9	−2.7		

RELATIVE HUMIDITY (PER CENT.)

Altitude	Broken Arrow Mean	Dep.	Drexel Mean	Dep.	Due West Mean	Dep.	Ellendale Mean	Dep.	Groesbeck Mean	Dep.	Royal Center Mean	Dep.
Surface	71	+4	78	+1	63	−5	75	−6	75	0	84	+6
250	70	+3			63	−5			72	−1	84	+6
500	64	−1	74	−1	61	−5	73	−7	70	0	81	+3
750	62	0	68	−3	61	−4	67	−7	66	0	73	−2
1,000	59	+1	63	−3	60	−4	63	−7	61	−1	65	−6
1,250	57	+2	60	−2	59	−4	60	−6	58	−1	63	−5
1,500	54	+1	57	−2	57	−4	55	−7	55	0	60	−4
2,000	46	−3	54	−1	53	−4	50	−9	54	+5	59	+1
2,500	44	−4	53	0	51	−5	48	−11	50	+5	58	+2
3,000	41	−4	51	−2	51	−2	48	−10	48	+5	64	+8
3,500	40	−3	51	−2	49	−2	47	−9	46	+5	73	+17
4,000	40	−3	51	0	49	−2	46	−9	43	+6	82	+26
4,500	39	−3	52	+1	48	−2	60	+6	39	+10		
5,000	39	−3	52	+1	48	−2	74	+16	34	+9		

VAPOR PRESSURE (*mb.*)

Altitude	Broken Arrow Mean	Dep.	Drexel Mean	Dep.	Due West Mean	Dep.	Ellendale Mean	Dep.	Groesbeck Mean	Dep.	Royal Center Mean	Dep.
Service	6.18	+0.11	4.28	+0.54	5.89	−2.18	2.96	+0.48	8.39	−1.26	4.05	−0.14
250	6.14	+0.12			5.79	−2.17			7.98	−1.21	3.93	−0.19
500	5.40	+0.07	4.06	+0.51	5.27	−1.93	2.88	+0.44	7.28	−0.95	3.28	−0.32
750	4.80	+0.09	3.70	+0.48	4.96	−1.79	2.69	+0.40	6.68	−0.88	2.84	−0.41
1,000	4.44	+0.20	3.55	+0.50	4.97	−1.47	2.67	+0.43	6.22	−0.65	2.48	−0.51
1,250	4.19	+0.32	3.42	+0.50	4.60	−1.39	2.56	+0.39	5.72	−0.49	2.24	−0.43
1,500	3.80	+0.29	3.20	+0.49	4.14	−1.34	2.34	+0.32	5.17	−0.25	2.05	−0.34
2,000	2.99	+0.15	2.70	+0.42	3.60	−0.80	1.81	+0.10	4.23	+0.06	1.92	−0.02
2,500	2.49	+0.11	2.22	+0.33	3.17	−0.41	1.47	+0.03	3.21	−0.09	1.54	−0.11
3,000	1.99	+0.11	1.77	+0.22	2.55	−0.28	1.31	+0.18	2.72	−0.05	0.80	−0.55
3,500	1.60	+0.11	1.41	+0.17	2.05	−0.38	1.12	+0.25	2.28	+0.02	0.22	−0.81
4,000	1.28	+0.12	1.17	+0.23	1.48	−0.38	0.96	+0.25	1.80	+0.04		
4,500	0.98	+0.12	1.09	+0.31	1.05	−0.38	1.03	+0.45	1.34	+0.22		
5,000	0.80	+0.12	1.09	+0.37	0.77	−0.38	0.95	+0.53	0.96	+0.17		

TABLE 2.—*Free-air resultant winds (m. p. s.) during February, 1924*

Altitude, m. s. l. (m.)	Broken Arrow, Okla. (233 meters) Mean Dir.	Vel.	6-year mean Dir.	Vel.	Drexel, Nebr. (396 meters) Mean Dir.	Vel.	9-year mean Dir.	Vel.	Due West, S. C. (217 meters) Mean Dir.	Vel.	3-year mean Dir.	Vel.	Ellendale, N. Dak. (444 meters) Mean Dir.	Vel.	7-year mean Dir.	Vel.	Groesbeck, Tex. (141 meters) Mean Dir.	Vel.	6-year mean Dir.	Vel.	Royal Center, Ind. (225 meters) Mean Dir.	Vel.	6-year mean Dir.	Vel.
Surface	N.45°W.	2.1	N.29°W.	0.9	S. 62° E.	0.2	N.66°W.	1.4	N.66°W.	1.8	W.	1.6	N.20°W.	3.2	N.44°W.	3.6	N. 7°W.	1.5	N.22°W.	0.5	N.70°W.	1.9	S. 85° W.	2.1
250	N.45°W.	2.1	N.34°W.	0.7					N.65°W.	1.9	N.88°W.	4.4					N.11°W.	1.6	N 38°W.	0.4	N.76°W.	2.0	S. 82° W.	2.3
500	N.58°W.	2.0	N.71°W.	0.6	N.76°W.	0.4	N.71°W.	2.0	N.72°W.	2.5	W.	3.1	N.21°W.	3.0	N.48°W.	3.8	N.16°W.	1.1	S. 42° W.	0.8	N.84°W.	3.5	S. 71° W.	3.6
750	N.48°W.	2.6	S.70° W.	1.5	N.54°W.	1.7	N.69°W.	4.1	S. 84° W.	3.6	S. 81° W.	4.6	N. 4°W.	1.7	N.53°W.	4.8	N.36°W.	1.2	S. 48° W.	1.6	S. 78° W.	4.2	S. 71° W.	5.2
1,000	N.57°W.	2.5	S.70° W.	2.6	N.34°W.	2.5	N.65°W.	5.3	S. 81° W.	4.3	S. 79° W.	5.7	N.23°W.	2.0	N.23°W.	5.3	N.72°W.	2.1	S 63° W.	2.9	S. 82° W.	5.2	S. 76° W.	6.5
1,250	N.63°W.	3.5	N.88°W.	3.5	N.40°W.	3.8	N.65°W.	6.5	S. 81° W.	5.5	S. 81° W.	7.2	N.32°W.	3.2	N.53°W.	6.4	N.82°W.	3.3	S 73° W.	4.1	N.73°W.	5.8	S. 85° W.	7.7
1,500	N.58°W.	4.6	N.82°W.	4.4	N.45°W.	4.7	N.65°W.	8.4	N.82°W.	7.9	S. 84° W.	9.1	N.24°W.	3.6	N.57°W.	7.5	S. 85° W.	5.5	S. 79° W.	5.6	N.69°W.	6.6	S. 88° W.	9.1
2,000	N.60°W.	5.7	N.76°W.	6.5	N.49°W.	6.9	N.67°W.	10.3	N.80°W.	11.1	S. 87° W.	12.6	N.26°W.	5.4	N.61°W.	9.4	N.86°W.	7.0	S. 84° W.	7.6	N.60°W.	11.3	N.87°W.	11.0
2,500	N.68°W.	6.5	N.74°W.	7.4	N.53°W.	11.2	N.68°W.	12.7	N.88°W.	13.1	S. 85° W.	14.7	N.24°W.	7.1	N.64°W.	11.5	N.81°W.	7.7	W.	8.6	N.72°W.	14.8	N.83°W.	13.6
3,000	N.70°W.	7.7	N.79°W.	10.6	N.56°W.	10.1	N.73°W.	14.4	N.88°W.	13.4	S. 86° W.	15.9	N.21°W.	10.3	N.65°W.	12.8	N.69°W.	7.7	W.	10.7	S. 81° W.	18.1	N.86°W.	14.6
3,500	N.56°W.	6.4	N.65°W.	10.9	N.65°W.	11.5	N.73°W.	15.7	N.74°W.	14.0	N.83°W.	17.1	N.37°W.	8.4	N.69°W.	12.2	N.58°W.	9.0	N.86°W.	11.4	S. 45° W.	13.0	N.83°W.	17.6
4,000	N.59°W.	9.0	N.62°W.	10.3	N.60°W.	14.6	N.78°W.	15.9	S. 83° W.	12.0	S. 83° W.	12.0	N.30°W.	11.9	N.65°W.	13.4	N.64°W.	8.7	N.83°W.	12.1	S. 45° W.	11.6	N.82°W.	17.5
4,500	N.44°W.	9.9	N.51°W.	12.6	W.	12.4	N.83°W.	17.0	S. 68° W.	15.0	S. 68° W.	15.0	N.30°W.	12.8	N.63°W.	14.1	N.57°W.	7.9	N.74°W.	12.5				
5,000	S. 45° W.	11.5	S. 45° W.	11.5	N.70°W.	11.8	N.81°W.	16.3	S. 68° W.	16.6	S. 68° W.	16.6	N.68°W.	16.4	S. 84° W.	18.6	N.51°W.	8.2	N.49°W.	10.1				

THE WEATHER ELEMENTS

By P. C. DAY, Meteorologist, in Charge of Division

PRESSURE AND WINDS

Probably the most pronounced factor influencing the weather over the United States during February, 1924, was the persistence of high barometric pressure from the upper Mississippi Valley westward to the middle Plateau region. This was not due, as is usually the case, to the movement of high-pressure areas from the Canadian Northwest, as only a few important projections southward of the so-called polar front entered the United States during the month, but rather to high-pressure areas from the Pacific Coast States increasing somewhat in force after entering the continental United States and drifting slowly to the eastward.

As a result, a ridge of high barometric pressure was built up to the southward of the Canadian border, extending in a more or less east-west direction between Lake Superior and northern California. From this ridge southerly winds overspread the districts in the United States immediately to the northward, as well as the adjacent Canadian Provinces, carrying to those regions the warmth of more southern latitudes with resulting average temperatures in some localities the highest ever known in February.

On the other hand, the flow of air over the eastern and southeastern districts, due to the same cause, was mainly from northerly points, carrying the temperatures of these regions to latitudes materially southward and giving persistent and unseasonable cold over the Eastern and Southeastern States.

The most important anticyclone of the month, as affecting the temperature, moved into the Dakotas and Minnesota by the morning of the 4th, and rather sharp falls in temperature occurred in the Great Plains as far south as central Texas. Due to a storm passing northeastward toward the Great Lakes, the effects of this anticyclone in lowering the temperature were mainly felt to the southward of the storm center and cold weather persisted in the Southern and Southeastern States for a considerable period.

About the middle of the month another anticyclone entered the upper Missouri Valley and moved eastward, but important lowering of the temperature was confined mainly to the more northern districts. The latter half of the month was without anticyclones that materially lowered the temperature over extensive areas.

The cyclones of the month attained importance principally over the eastern portions of their courses and occurred mainly over the central and southern districts. One of the most extensive of these, particularly as to area covered and amount of precipitation, developed early in the month over the far Southwest, but in the main caused little precipitation until after reaching the middle Plains on the morning of the 3d. During the following two or three days it moved slowly eastward and northeastward, attended by snow or rain over the greater part of the country from the Mississippi Valley eastward. Over a considerable area from Oklahoma and Kansas northeastward to the upper Lakes there were heavy falls of snow and in portions of this area heavy glaze formed. High winds drifted the snow badly, causing much delay to transportation interests, and the extensive ice coating damaged overhead wires, trees, etc. To the southward of the storm center precipitation was mostly rain, heavy in some localities, and local winds of tornadic character occurred in a few localities, notably in northern Alabama, where some loss of life occurred.

On the morning of the 16th cyclonic conditions developed over the Southern Plains and moved eastward to the middle Mississippi Valley during the following 24 hours, and later the storm's influence extended to the middle Atlantic coast, although it appears to have lost its identity and probably merged later into another that advanced northeastward from the middle Gulf coast, which combined with a second low area moving southeastward from the upper Missouri Valley about the same time. A general combination of these had been accomplished by the morning of the 19th and rains and snows had fallen over the greater part of the country from the Great Plains eastward, continuing during the following 24 hours over the more northeastern districts.

The precipitation from this combination of storms was heavy over the Gulf and Atlantic Coast States and in portions of the Ohio Valley, and heavy snow fell from the Middle Atlantic States to New England. High winds and gales along the Atlantic coast and drifting snow with extensive glaze formation in parts of the affected area caused much delay to traffic of all kinds, and damage to overhead communications.

On the morning of the 24th threatening cyclonic conditions were noted over the west Gulf, and by the following morning rain had occurred in that section as well as over portions of the Southeast. This storm developed materially and at the end of the following 24 hours was central in the vicinity of Mobile, Ala., as a storm of considerable severity. It moved to the eastward of the Carolina coast by the 27th and thence to sea. Heavy rains occurred in connection with this storm over the Gulf and South Atlantic States, and considerable snow fell in the southern Appalachian Mountains and adjacent highlands.

Practically no important cyclones entered the United States from the north Pacific coast, a point of frequent origin for winter storms, and the entire country from the Rocky Mountains westward to the Pacific was unusually free from the severe storms usual to a winter month.

The mean sea-level pressures for the month were above the normal in all portions of the United States and Canada, as far as observations disclosed, save along the Atlantic coast from southern New England to northern Florida, the departures being large from Lake Superior westward to Oregon and northern California. Over the Atlantic coast districts the pressure averages were mainly slightly less than normal.

Compared with the preceding month, the pressure was nearly everywhere less, save from the Dakotas eastward to northern New England, generally over the central and eastern Canadian Provinces, and locally along the immediate Pacific coast. As a rule the pressure for February is less than for January over all parts of the country save the areas adjacent to eastern Lake Superior, and along the Pacific coast.

Severe local storms were limited to a few localities, mainly on the 4th, but winds were high over the middle Mississippi Valley and thence northeastward to the upper Lakes about the 4th to 5th and along the Atlantic coast on the 19th and 20th. High winds were much less frequent on the Pacific coast than is usually the case in February.

TEMPERATURE

The outstanding feature of the temperature survey for both the United States and Canada is the marked warmth that persisted so uniformly during the month from the Great Lakes westward and southwestward to the Pacific coast, and the less marked, but persistent coolness over the Eastern and Southeastern States.

From the Dakotas westward to the Pacific the month was mainly warmer than normal throughout, and in portions of Idaho, Oregon, and Washington every day of the month had temperatures above normal, while in adjacent States only from one to three days were cooler than normal. In portions of this area the monthly means were the highest ever known in February, and at a few points the maximum temperatures were likewise the highest of record so early in the year. On the other hand, the month was decidedly cold in New England and generally over the Atlantic and Gulf States, where in some localities, particularly in New England, temperatures were below normal nearly every day.

A notable feature of the temperature for the month as a whole was the absence of important day-to-day changes. This particular feature is commented on by the official in charge at Chicago, Prof. H. J. Cox, as follows:

> Attention is invited to a most unusual condition, embracing certain temperature features of the two successive months of January and February, 1924. The mean daily variability for January was 11.3°, the highest of record for any month whatever, while the mean for February was 3.4°, the lowest for any winter month, and among the lowest for any month of the year. Another feature of February was the low mean daily range of temperature. This was 8.9°, which is the lowest of record for any month, with the single exception of 8.4° for December, 1918.

This evenness of temperature was likewise noted at other points, both in the regions of persistent cold as well as in those of continued warmth.

The warmest periods of the month varied in different portions of the country, ranging from the 2d to 5th over the area extending from the Dakotas southeastward to the Middle Atlantic States; from the 12th to 14th, over most districts from the Rocky Mountains westward; about the 15th to 18th, over the Southeastern States; and from the 26th to 28th, over the northern tier of States from Minnesota to New England.

The highest temperature reported during the month, 95°, occurred on the 4th, at San Benito, Tex.

The coldest periods were 1st to 4th over most districts west of the Rocky Mountains; 5th to 9th, from Texas and Oklahoma eastward to the Middle Atlantic States; and 20th to 25th, from Montana and Wyoming eastward to the Great Lakes and portions of the Middle Atlantic States.

Freezing temperatures occurred in all the States of the Union, although the greater part of Florida and the extreme southern portions of the Gulf States and the immediate Pacific coast section had none.

The lowest temperature reported during the month, −35°, occurred at Humboldt in northern Michigan.

PRECIPITATION

Considering the country as a whole, the precipitation was deficient over probably more than two-thirds of the area, though the amounts received to eastward of the Great Plains were mainly sufficient for present needs.

Portions of Florida and the West Gulf States had local areas with more than the normal fall, and likewise in the Atlantic Coast States from the Carolinas to southern New England there were areas with amounts above normal.

From the Great Plains westward the precipitation was nearly everywhere deficient save in South Dakota and small portions of adjacent States, and in the far Northwest, where slight excesses occurred.

In most of the mountain regions of the West the light precipitation was due to a general deficiency of snowfall, which was nearly everywhere far less than normal. This was particularly the case in the central and southern portions of the area, where the monthly precipitation was frequently the least of record.

In California, where drought had persisted since the beginning of the season, February brought no material relief and at the end of the month less than 50 per cent of the normal precipitation for the season up to that time had been received. Similar conditions exist in Nevada, Utah, Arizona, and portions of adjacent States.

In the districts east of the Rocky Mountains precipitation was heaviest in eastern Texas, where amounts up to slightly more than 8 inches fell, and amounts nearly as large were reported locally in the other Gulf States. In the far West the greatest falls, nearly 25 inches, occurred near the Washington coast, while considerable areas in southern California, and the adjacent portions of Nevada and Arizona, had no precipitation during the entire month.

SNOWFALL

Over a considerable area, from the eastern portions of Colorado and Wyoming to the Great Lakes, there was generally more snow than usual in February, due mainly to the heavy falls attending the storm of the 3d to 5th over that region, and the storm of the 19th and 20th brought heavy snows from the southern Appalachian Mountains to New England. Over other areas east of the Rocky Mountains the snow during the month was mainly light.

From the Rocky Mountains westward the snowfall was mainly far less than normal, as stated previously, particularly in the mountains of California, and generally over the Plateau districts.

At the end of the month the stored snow in the mountains of California was far less than usual and in some sections probably less than ever known before.

Streams were at low stages and the prospects for an adequate supply of water for the coming dry season declined as the month progressed. In many other portions of the central and southern mountain States the supply of snow in the mountains at the end of the month ranged from less than one-half to as little as one-third of the normal.

At the end of the month the snow cover over the eastern half of the country had mainly disappeared save in the upper Lake region and from the mountain regions of Maryland northeast to New England. In the western mountain districts only the more elevated portions had a material covering.

RELATIVE HUMIDITY

Due to general warmth in the West and Northwest and absence of the usual amount of precipitation over large areas, the relative humidity for the country as a whole was less than the normal, the deficiencies in the far Southwest being unusually large. Over New England and generally in the Lake region the percentage of relative humidity was higher than normal.

SEVERE LOCAL STORMS, FEBRUARY, 1924

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Middle West and Upper Lake region.	3-6					Wind, sleet, snow, and ice.	Train service demoralized, telegraph and telephone poles and wires broken, highways impassable for days. Damage amounts to hundreds of thousands of dollars.	Official, U. S. Weather Bureau. Telegraph Herald (Dubuque, Iowa). Journal of Commerce (Chicago); Courier (Evansville, Ind.).
Rocky Ridge, Ala. (12 miles south of Birmingham).	4	p. m.		2		Tornado	One home demolished and 5 persons injured	Official, U. S. Weather Bureau.
Jack, Coffee County, and Tarentum, Pike County, Ala.	4	9 a. m.				do	Some buildings destroyed	Do.
Southern Indiana	4	3 p. m.			$100,000	do	Houses and barns destroyed and orchards ruined near Haubstadt; livestock injured and houses damaged near Howell.	Official, U. S. Weather Bureau. Courier (Evansville, Ind.).
Rockingham and Caswell Counties through Iredell to Henderson County, N. C.	19-20				$200,000	Heavy sleet	Great damage to telephone and telegraph lines and timber. Path 60 miles wide in northern portion and narrow strip at southern end.	Official, U. S. Weather Bureau.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

A storm of marked intensity moved slowly east-northeastward from the lower Missouri Valley to southern New England during the 3d-6th. It was attended by strong shifting winds and gales along the Atlantic coast from Cape Hatteras northward, the highest velocity reported being 52 miles an hour from the east at Block Island, R. I. The necessary warnings were issued well in advance of the occurrence of the high winds.

No further storm warnings were required until the 19th, when a disturbance of moderate intensity was central south of the Louisiana coast and an area of abnormally high pressure covered the Lake region and the middle Atlantic and north Atlantic States. Northeast storm warnings were ordered displayed from Jacksonville, Fla., to Eastport, Me., and they were fully verified from Wilmington, N. C., northward, the following high-wind velocities being reported: Atlantic City, N. J., 68 m. p. h. from SE.; Block Island, R. I., 60, E.; Nantucket, Mass., 60, SE.; and Eastport, Me., 56, E.

During the 25th a storm developed over the western Gulf of Mexico and moved northeastward to southern Alabama, then almost directly eastward to the Georgia coast, after which it turned northeastward, its center passing close to Cape Hatteras at noon of the 27th, the barometer reading 29.26 inches at that place. Continuing its northeastward movement the center of the storm reached Sable Island the morning of the 28th, with a barometer reading of 28.90 inches there. During the 28th its course turned more to the northward and as the storm passed Port aux Basques, N. F., the wind attained a velocity of 94 miles an hour from the east. Storm warnings were ordered in advance of this storm at all points from Bay St. Louis, Miss., eastward on the Gulf coast and along the Atlantic coast as far north as Boston, Mass. The highest wind velocity reported in the South was 36 miles an hour from the northwest at Key West, Fla., but it reached 56 miles an hour from the north at both Cape Henry, Va., and Cape Hatteras, N. C.

Small-craft warnings were displayed along a part of the east Gulf coast on the 4th and 19th, and along portions of the Atlantic coast from Cape Hatteras northward on the 5th, 10th, and 12th.

No cold-wave warnings were issued during the month, except for a part of northern New York on the 15th.

Frost warnings for the south Atlantic and east Gulf coast sections were issued frequently during the first two weeks of the month and on three dates thereafter. There was an unusually extended period of cool weather in these sections from the 6th to the 11th, inclusive, frost occurring at Jacksonville on the morning of the 6th and at least as far south as the interior of central Florida during the five succeeding nights.

Heavy-snow warnings were issued for New England and western New York, and warnings of heavy snow, sleet, or rain for western Pennsylvania and for the Atlantic States from southern New England to Delaware, inclusive, on the morning of the 19th. These warnings were fully verified. Several stations reported depths of snow on the ground the following morning ranging from 8 inches at Harrisburg, Pa., to 15 inches at Northfield, Vt. At Pittsburgh, Pa., there was an ice and sleet storm during the night of the 19th-20th that coated all exposed objects with ice from half to three-quarters of an inch in thickness. As a result, telephone and telegraph communication throughout the Pittsburgh district was almost entirely disrupted on the morning of the 20th, and communication by radio was resorted to in some cases during the 20th from Pittsburgh to points in the surrounding territory.

Warnings of heavy snow, or heavy snow and rain, were also issued for a considerable area from Ohio eastward in connection with the Gulf storm of the 26th, but they were not verified because of the eastward movement of the storm center from the interior of Alabama to the Georgia coast during the 26th. It was expected that the storm would advance northeastward during the succeeding 24 hours at least.—*Charles L. Mitchell.*

CHICAGO FORECAST DISTRICT

The month, as a whole, was exceptionally mild, the temperature in the Northwestern States ranging from 10° to 15° above the seasonal normal. The temperature, moreover, varied but little from day to day, and this was in strong contrast to the frequent and great changes during the preceding month of January. While the daily variability in January exceeded all records at several points, the absence of variability in February was fully as marked.

No widespread cold waves moved across the district during the entire month, and no general warnings were issued.

However, there were three storms of considerable importance. The first caused general rain, snow, and sleet on the 3d, 4th, and 5th; the second from the 16th to the 20th; and the third from the 22d to the 24th. The last storm was attended by rather heavy snow in portions of Iowa and Nebraska.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT

On February 2 a depression of marked intensity developed rapidly on the middle and southern Rocky Mountain slope. This storm moved slowly eastward during the next few days, with steep barometric gradient in the rear, attended by strong north to west winds and snow over the southern slope. Northwest storm warnings were issued for the east coast of Texas at 8:30 p. m. on the 3d; and winds occurred as forecast, the highest at Galveston being 42 miles an hour from the northwest on the following afternoon.

On the morning of the 25th, with a disturbance forming on the west Gulf coast and high barometric pressure to the northward, northwest storm warnings were ordered at 8:20 a. m. for the Texas coast from Port Arthur to Freeport and small-craft warnings west of Freeport to Brownsville. The storm warnings were extended at night along the Louisiana coast and were succeeded the next morning by small-craft warnings on the east coast of Texas. Winds occurred as indicated in the warnings.

In connection with the storm of the 3d-4th, cold-wave warnings for Oklahoma, Arkansas, and northern Texas were issued at night on the 3d, northwestern Louisiana being included the next morning and the east coast of Texas on the afternoon of the 4th. The cold wave occurred as forecast.

Cold-wave warnings were issued on the morning of the 19th for Oklahoma and the north portion of West Texas and were extended the following morning over northern Arkansas. A large area of high pressure, moving down the Rocky Mountain slope, was attended by temperatures about as low as predicted; but the advance of colder weather was rather gradual, the lowest temperatures occurring on the morning of the 21st.

Stockmen were warned of the cold waves and accompanying conditions.

Warnings of frost or freezing temperatures, or lower, in the extreme southern sections, were issued on the 4th, 5th, 12th, 20th, 21st, 25th, 26th, 27th, and 28th, and were generally verified.

Fire-weather warnings were sent to Arkansas on the 4th and to Oklahoma on the 19th, for winds of more than ordinary velocity.—*R. A. Dyke.*

DENVER FORECAST DISTRICT

No cold waves occurred in the Denver Forecast District during the month and no cold-wave warnings were issued. Low-pressure areas, whose centers passed over the district, were notably lacking in energy. Transitions from mild to cold weather were either comparatively gradual, or the fall was not sufficiently great to constitute a cold wave. On Saturday morning, the 2d, a shallow low-pressure area extended from the northern Rocky Mountain region to the north Atlantic coast with but little variation in barometer readings and apparently with several minor centers of action, while the nearest high-pressure area was central off the coast of northern California. In addition to the forecast for eastern Colorado of unsettled and somewhat colder weather Sunday, a stockmen's warning would have proved beneficial, for by Sunday morning a slow-moving disturbance of marked intensity had developed over eastern Kansas. Although the temperature in eastern Colorado fell only to about freezing, there was a high wind, which was accompanied by light snow in the extreme eastern and northeastern portions of the State. One correspondent reported losses in his locality.

On the morning of the 8th the temperature was near the critical point at Yuma, and the pressure distribution indicated the possibility of a movement that would cause slightly lower temperature, consequently light frost was predicted for extreme southwestern Arizona, but on the following morning the minimum temperature was still a few degrees above the critical point.—*Lawrence C. Fisher.*

SAN FRANCISCO FORECAST DISTRICT

February, 1924, opened with a LOW over the Gulf of Alaska and rather high pressure over Bering Sea. The LOW extended sufficiently far southeastward to cause rain in northern California on the first day of the month. An offshoot from the LOW over the Gulf of Alaska was at the same time in evidence over Saskatchewan. This offshoot moved eastward and by the 4th had developed into a severe storm over the lower Ohio valley. In the meantime the parent LOW over the Gulf of Alaska gained in energy and impinged upon the British Columbia and southeastern Alaska coasts. By the morning of the 5th an offshoot appeared over British Columbia that eventually developed into a trough of low pressure that extended from Saskatchewan southwestward to the Gulf of California. During the formation of this trough of low pressure, the barometer rose over the North Pacific States and the rains then ceased, after having been more or less continuous since the 1st of the month. The trough of low pressure, however, caused the best rains of the month in California, though they amounted to very little in the southern portion of that State.

The Gulf of Alaska LOW remained nearly stationary until the 12th, when it moved eastward through Canada without causing any rain of consequence in the San Francisco Forecast District. A remarkable feature of this LOW was its great intensity at times and the fact that notwithstanding the high pressure over Bering Sea and Alaska the storm was not forced southward, but instead took the northern track across Canada and the United States.

On the 13th a small low-pressure area over southern California moved northward and the next day was in evidence near Vancouver Island. The following day it appeared as a trough of low pressure which extended from the Gulf of Alaska southeastward to the Texas Pan Handle. The southern end formed a LOW over the Texas Pan Handle, and the northern portion developed into a storm, which on the morning of the 16th was central about 500 miles off the Washington coast. This moved rapidly inland to British Columbia and thence southeastward, where lack of moisture evidently soon caused it to dissipate.

Another storm of great intensity was central near Dutch Harbor on the morning of the 18th. This, like the one during the fore part of the month over the Gulf of Alaska, moved back and forth with varying degrees of intensity till the close of the month without causing much precipitation and but few high winds in this district, though gales frequently occurred over the Great Circle track of steamships between North Pacific seaports as far west as 170° east longitude.

Storm warnings were ordered from San Francisco north, mostly at coast stations, on the 3d, 4th, 7th, 11th, 16th, 19th, 25th, and 29th; and nearly all were verified. Warnings for light to heavy frost were issued for California places on the 2d, 10th, and 11th.—*E. A. Beals.*

RIVERS AND FLOODS

By H. C. Frankenfield, Meteorologist

An inspection of the table at the end of this report will show that there were no floods of consequence during the month of February. There were moderate floods in some of the South Atlantic and East Gulf rivers, and in the majority of the tributary streams of the Ohio River. There were also unimportant rises in the Illinois River, the Yazoo River of Mississippi, and the Sulphur and lower Trinity Rivers of Texas. All of these floods were properly forecast, and the resulting losses were insignificant. In North and South Carolina property valued at $27,000 was saved through the warnings.

In the Arkansas River from Cimarron to Wichita, Kans., ice jams from February 5 to 13, inclusive, were productive of local floods. The ice conditions were said to have been the most severe in the history of the State of Kansas so far as is known, and extended for about 300 miles. Warnings were issued beginning with February 6, and thereafter when necessary until the ice had passed out. These warnings were the means of saving a large quantity of property and the reported losses were only $15,050. A number of letters was received from interested parties highly commending the warnings issued from the Wichita office of the Weather Bureau.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE					
Neuse:	Feet			Feet	
Smithfield, N. C	14	21	23	16.1	21–22
Cape Fear:					
Elizabethtown, N. C	22	21	24	27.2	23
		29	(1)		
Peedee:					
Mars Bluff, S. C	17	23	25	17.5	24
Santee:					
Rimini, S. C	12	(2)	5		
		23	(1)	13.2	25
Ferguson, S. C	12	(2)	7		
		24	(1)		
Broad:					
Blairs, S. C	15	28	29	16.2	28
Saluda:					
Chappels, S. C	14	28	(1)	14.8	28
Broad:					
Carlton, Ga	11	27	27	11.0	27
Ocmulgee:					
Abbeville, Ga	11	1	2	11.9	1
EAST GULF DRAINAGE					
Tombigbee:					
Lock No. 4, Demopolis, Ala	30	27	(1)		
Black Warrior:					
Lock No. 10, Tuscaloosa, Ala	46	28	(1)	51.0	28
Chickasawhay:					
Enterprise, Miss	21	28	(1)		
West Pearl:					
Pearl River, La	13	(2)	9		
MISSISSIPPI DRAINAGE					
Monongahela:					
Lock No. 15, Hoult, W. Va	22	20	21	26.4	20
Lock No. 10, Morgantown, W. Va	25	20	20	26.1	20
Lock No. 7, Martin, Pa	30	20	21	30.8	20
Lock No. 4. Pa	31	21	21	32.8	21
Little Kanawha:					
Glenville, W. Va	23	20	20	26.2	20
Creston, W. Va	20	20	21	21.8	20
Hocking:					
Athens, Ohio	17	21	21	17.1	21
Green:					
Lock No. 4, Woodbury, Ky	33	22	23	33.9	23
Wabash:					
La Fayette, Ind	11	(2)	1	[3] 22.0	1
Terra Haute, Ind	16	3	9	17.2	3, 6
Vincennes, Ind	14	7	13	15.3	10
Mount Carmel, Ill	16	6	12	17.8	10, 12
White, West Fork:					
Edwardsport, Ind	14	5	9	16.0	7
Illinois:					
Peru, Ill	14	1	19	16.4	9
		29	(1)		
Henry, Ill	7	1	29	9.6	12
Peoria, Ill	16	10	17	16.4	12–13
Havana, Ill	14	14	17	14.0	14–17
Beardstown, Ill	12	5	(1)	14.3	17
Arkansas:					
Dodge City, Kans	5	7	8	6.3	7
Yazoo:					
Yazoo City, Miss	25	(2)	11	26.0	4–5
Tallahatchie:					
Swan Lake, Miss	25	(2)	6		
Sulphur:					
Finley, Tex	24	(2)	1		
North Platte:					
North Platte, Nebr	5	(4)	14		
		27	(1)		
WEST GULF DRAINAGE					
Sabine:					
Logansport, La	25	29	(1)		
Trinity:					
Liberty, Tex	25	28	(1)		
Guadalupe:					
Gonzales, Tex	22	20	20	22.5	20
Victoria, Tex	16	21	23	19.2	22

[1] Continued at end of month. [3] Ice gorge.
[2] Continued from last month. [4] Unknown; measurement impracticable prior to 12th.

MEAN LAKE LEVELS DURING FEBRUARY, 1924

By United States Lake Survey

[Detroit, Mich., March 4, 1924]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes [1]			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during February, 1924:	Feet	Feet	Feet	Feet
Above mean sea level at New York	601.33	578.71	571.27	244.85
Above or below—				
Mean stage of January, 1924	−0.23	+0.13	−0.02	+0.08
Mean stage of February, 1923	−0.28	−0.13	+0.44	+0.38
Average stage for February last 10 years	−0.57	−1.17	−0.22	−0.44
Highest recorded February stage	−1.15	−4.01	−2.48	−2.82
Lowest recorded February stage	+0.57	−0.13	+0.64	+1.02
Average relation of the February level to:				
January level		(2)	−0.2	(2)
March level		−0.1	−0.2	−0.2

[1] Lake St. Clair's level: In February, 1924, 573.16 feet. [2] Practically no difference.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, FEBRUARY, 1924

By J. B. Kincer, Meteorologist

The first and middle parts of February were generally favorable for farm work in the Southern States, and the preparation of soil for spring planting made fairly good progress, although there was little plowing done in Oklahoma, and there was considerable delay in Arkansas and Tennessee by wet or frozen soil. It was too cool, however, for best growth of truck crops during much of the time in the Southeastern States, and there was considerable frost injury well toward the southern portion of the Florida Peninsula. In the west Gulf section temperatures were more favorable for truck and fairly good progress was reported. The latter part of the month was generally cold, cloudy, wet, and unfavorable for farm work throughout t e South, although conditions were fairly favorable in parts of Florida. Planting was delayed and there was some damage by frost, while germination of truck crops was slow. At the close of the month, however, planting of early potatoes had been about completed in the commercial districts of South Carolina, and some progress had been made in the preparation of tobacco seed beds in Virginia.

The weather was rather unfavorable for wheat in the Ohio Valley area, where there was much complaint of damage by alternate freezing and thawing, especially in Kentucky and the southern portions of Indiana and Illinois. At the close of the month wheat was greening

some in Missouri and was mostly in satisfactory condition, while favorable reports were received generally from the Great Plains States. Fall-seeded grains needed more moisture, however, in the Plateau districts of the West, but rainfall was beneficial in central and north Pacific States.

It was mostly unfavorable for seeding spring oats, especially the latter part of the month, where this work is usually in progress during February. Some oats had been sown at the close, however, northward to south-central Kansas, and seeding made fairly good progress in the extreme lower Great Plains. Some rice land was prepared in California and Louisiana.

The month was generally favorable for livestock interests in the great western grazing districts, although the cold, stormy conditions early in the month in the central Great Plains were hard on stock, especially in Kansas and Nebraska, while pastures continued short in Oklahoma. The range remained in good condition in Texas, except locally in the western portion where it was too dry, and there was sufficient precipitation in much of the far Southwest to benefit range land. More moisture was needed, however, in the western Plateau districts, particularly in Utah and Nevada, while dry weather unfavorably affected pastures in southern California. Lambing made satisfactory progress the latter part of the month in southwestern districts, and shed lambing showed good results in the far Northwest.

The month, on the whole, was favorable for fruit. There was some complaint of injury to peach buds by cold weather in Missouri, and some buds were killed in Georgia, but on the whole frost damage during the month was not extensive. Early fruits were blooming in the east Gulf sections and parts of the Pacific coast, while the warm weather the last part of the month caused trees to blossom prematurely in Arizona. There was some damage by frost to berries in Florida, but citrus generally continued in good condition.

CLIMATOLOGICAL TABLES

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, February, 1924

Section	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	° F.	° F.		° F.			° F.		In.	In.		In.		In.
Alabama	47.0	−0.8	Selma	81	15	Valley Head	12	6	4.65	−0.67	Leeds	7.34	Union Springs	1.43
Alaska														
Arizona	48.7	+2.5	Continental	92	[2] 7	Springerville	3	[2] 3	0.05	−1.17	St. Johns	0.69	Ajo	0.00
Arkansas	42.9	+0.7	Subiaco	82	14	Gravette	−7	6	2.26	−1.02	Portland	6.36	Fayetteville	0.60
California	53.3	+4.8	2 stations	91	[2] 13	Helm Creek	−9	11	1.76	−2.50	Inskip	10.02	29 stations	0.00
Colorado	31.4	+4.6	Lamar	80	14	Dillon	−30	24	0.51	−0.58	Savage Basin	2.41	7 stations	T.
Florida	58.0	−2.6	Gainesville	88	19	4 stations	24	10	3.30	+0.17	Arcadia	6.86	Sand Key	0.38
Georgia	46.7	−1.2	Valdosta	84	[2] 15	Clayton	10	22	3.96	−1.01	Clayton	7.35	Brunswick	1.89
Hawaii														
Idaho	35.5	+7.3	stations	67	[2] 14	Warren	−9	9	1.55	−0.10	Warren	5.63	Deer Flat	0.02
Illinois	30.5	+2.8	Harrisburg	70	3	Mount Carroll	−6	22	1.56	−0.52	Fairfield	2.37	Mount Vernon	0.66
Indiana	30.1	+0.9	Rome	70	3	Goshen	−6	23	1.62	−1.03	Valparaiso	2.39	Goshen	0.63
Iowa	25.8	+5.3	Clarinda	70	2	Decorah	−15	22	1.27	+0.12	Lacona	4.00	Algona	0.30
Kansas	35.7	+3.4	2 stations	81	14	2 stations	−10	21	0.82	−0.30	Walnut	3.55	Minneapolis	0.10
Kentucky	36.0	0.0	....do	71	[2] 3	Farmers	9	22	2.56	−0.97	Middlesboro	5.10	Louisville	1.46
Louisiana	52.5	−0.5	Newellton	81	16	Robeline	12	6	4.94	+0.37	Franklin	7.67	St. Francisville	2.06
Maryland-Delaware	32.4	0.0	Princess Anne, Md	68	5	Grantsville, Md	−13	24	3.47	+0.40	Millington, Md	4.48	Public Landing, Md	2.09
Michigan	19.9	+1.7	2 stations	52	26	Humboldt	−35	23	1.79	+0.10	Traverse City	3.10	Eagle Harbor	0.53
Minnesota	18.8	+8.1	Pipestone	66	28	2 stations	−29	22	0.52	−0.26	Grand Marais	1.80	Waskish	0.04
Mississippi	48.3	−0.3	Macon	83	15	Holly Springs	18	6	4.51	−0.43	Hickory	7.49	Hernando	1.53
Missouri	33.8	+2.0	Hollister	79	14	3 stations	−5	[2] 6	1.88	−0.27	Lamar	3.00	Seymour	0.60
Montana	31.5	+10.0	Chinook	67	12	Browning	−27	20	0.84	+0.06	Heron	3.82	Sunset Orchard	T.
Nebraska	30.7	+5.8	North Loup	72	2	2 stations	−15	[2] 8	0.82	+0.10	Ainsworth	2.70	Hebron	T.
Nevada	41.5	+6.8	Las Vegas	84	[2] 17	....do	2	[2] 1	0.55	−0.37	Owyhee	1.96	6 stations	0.00
New England	18.3	−3.8	Turners Falls, Mass.	54	27	Van Buren, Me	−28	9	2.38	−0.83	Bristol, R. I	4.45	Bethlehem, N. H	0.90
New Jersey	28.9	−1.0	Bridgeton	62	4	Layton	−3	25	4.10	+0.40	Indian Mills	6.11	Newton	2.45
New Mexico	38.8	+1.4	Boaz	85	10	Harvey's Upper Ranch.	−13	4	0.41	−0.33	Lee's Ranch	4.11	2 stations	0.00
New York	18.8	−2.8	2 stations	53	[2] 4	Wanakena	−26	18	2.66	−0.17	Flushing	4.92	Lauterbrunnen	0.64
North Carolina	39.9	−1.8	....do	76	5	Banners Elk	2	9	4.35	+0.28	Edenton	7.35	Cullowhee	2.01
North Dakota	20.3	+12.4	Berthold Agency	67	11	2 stations	−27	21	0.41	−0.08	Foxholm	1.01	2 stations	T.
Ohio	28.7	+0.1	Clarington	75	4	Canfield	−8	24	2.02	−0.47	Middleport	4.18	Defiance	0.9
Oklahoma	42.2	+2.8	Altus	88	15	Spavinaw	−5	6	0.93	−0.48	McAlester	3.55	Buffalo	T.
Oregon	43.0	+5.9	Riddle	74	13	Crater Lake	1	9	3.05	−0.52	Astoria	11.52	Silver Lake	0.05
Pennsylvania	26.9	−0.4	Uniontown	70	4	West Bingham	−25	24	2.94	+0.11	Pottsville	5.16	Erie	1.27
Porto Rico														
South Carolina	44.2	−2.8	Yemassee	78	18	2 stations	13	9	3.54	−0.85	Walhalla	6.32	Garnett	1.41
South Dakota	25.4	+8.1	Tyndall	68	2	La Delle	−23	21	0.93	+0.37	Spearfish	3.57	Victor	0.13
Tennessee	39.3	−1.0	3 stations	76	[2] 3	2 stations	6	[2] 7	3.99	−0.10	Clinton	5.83	Paris	1.44
Texas	49.8	−0.5	San Benito	95	4	Clint	8	5	2.49	+0.69	Freeport	8.31	Childress	0.00
Utah	35.9	+6.0	St. George	75	12	Panguitch	−7	1	0.28	−1.00	High Line City Creek.	1.74	12 stations	0.00
Virginia	35.5	−1.1	Runnymede	72	5	Burkes Garden	2	9	2.67	−0.47	Runnymede	4.27	Winchester	0.82
Washington	44.1	+7.4	Hanford	71	12	Snyder's Ranch	−1	9	4.42	+0.91	Forks	23.98	Attalia	0.27
West Virginia	31.6	−0.4	Janelew	74	4	Cheat Bridge	−16	16	3.21	+0.15	Pickens	8.18	Upper Tract	0.84
Wisconsin	20.3	+4.8	3 stations	50	[2] 26	Long Lake	−31	23	1.09	−0.03	Manitowoc	2.76	Iron River	0.22
Wyoming	27.6	+5.8	Pinebluff	68	14	Moran	−27	24	0.73	−0.04	Dome Lake	3.06	Powell	0.04

[1] For description of tables and charts, see REVIEW, January, 1924, pp. 56–57.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1924*

Districts and stations	Elevation of instruments: Barometer above sea level	Thermometer above ground	Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Departure from normal	Days with 0.01, or more	Wind: Total movement	Prevailing direction	Maximum velocity: Miles per hour	Direction	Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							21.8	−3.7										72	2.47	−1.0										4.9		
Eastport	76	67	85	29.89	29.98	.00	17.8	−3.7	37	27	25	0	19	10	23	15	8	64	1.07	−2.7	5	9,062	nw.	58	e.	20	11	8	10	5.3	8.1	5.6
Greenville, Me.	1,070	6	-----	28.80	30.04	-----	10.0	-----	40	27	20	−10	10	0	40	-----	-----	-----	2.24	-----	7	-----	ne.	-----	-----	-----	16	6	7	-----	22.5	27.5
Portland, Me.	103	82	117	29.92	30.05	+.03	19.8	−4.0	39	28	27	2	24	12	26	16	11	70	3.84	+0.1	8	6,281	nw.	37	e.	20	18	4	7	4.0	23.2	22.2
Concord	288	70	79	29.73	30.06	+.02	18.8	−4.0	44	27	28	−6	10	9	37	-----	-----	-----	1.57	−1.8	9	3,691	nw.	23	nw.	16	19	2	8	3.7	16.0	11.8
Burlington	404	11	48	29.64	30.12	+.09	12.0	−5.9	34	27	21	−10	9	3	30	-----	-----	-----	1.59	+0.2	9	5,781	n.	35	s.	20	9	7	13	6.2	20.8	11.7
Northfield	876	12	60	29.09	30.09	+.05	10.5	−6.7	39	27	23	−20	9	−2	44	8	5	86	2.19	−0.2	10	4,178	n.	28	sw.	21	8	8	13	6.2	27.5	15.9
Boston	125	115	188	29.89	30.03	−.01	26.6	−2.2	44	28	33	10	24	20	23	22	15	62	2.61	−1.0	7	7,458	w.	34	e.	20	15	6	8	4.4	10.4	1.0
Nantucket	12	14	90	29.99	30.00	−.04	29.8	−2.8	49	6	35	15	14	25	20	27	24	81	1.92	−1.3	7	10,584	nw.	58	se.	20	10	6	13	5.7	3.6	0.0
Block Island	26	11	46	29.98	30.01	−.05	28.0	−2.4	47	20	33	14	24	23	22	26	21	73	2.57	−1.8	6	14,642	nw.	60	e.	20	13	6	10	5.0	3.0	0.0
Providence	160	215	251	29.86	30.04	−.01	25.5	−3.5	43	2	32	9	24	19	24	22	16	69	3.67	−0.9	8	8,573	nw.	38	w.	21	15	4	10	4.5	7.4	T.
Hartford	159	122	140	29.87	30.05	−.01	24.9	−2.3	44	3	32	6	13	18	24	-----	-----	-----	2.98	−0.7	8	-----	nw.	-----	-----	-----	14	7	8	4.1	2.7	3.0
New Haven	106	74	153	29.94	30.06	−.01	26.2	−2.8	44	3	33	8	13	20	22	22	17	70	3.18	−0.7	9	6,562	ne.	33	nw.	16	16	4	9	4.4	9.8	0.5
Middle Atlantic States							31.5	−1.8										71	3.16	−0.2										5.8		
Albany	97	102	115	29.99	30.10	+.03	19.0	−5.1	39	27	27	0	13	11	32	17	13	80	1.59	−1.0	10	5,045	ne.	26	s.	10	13	5	11	5.1	11.3	1.0
Binghamton	871	10	84	29.08	30.05	−.03	21.3	−3.4	41	4	29	−10	24	13	40	-----	-----	-----	2.57	+0.6	11	4,358	nw.	28	se.	20	7	6	16	7.2	22.4	4.5
New York	314	414	454	29.71	30.07	−.01	29.2	−2.1	46	3	36	9	13	23	21	26	20	69	3.84	0.0	10	12,842	nw.	55	nw.	21	9	7	13	6.2	10.7	T.
Harrisburg	374	94	104	29.68	30.10	+.01	29.8	−0.4	46	2	36	12	24	24	21	26	20	69	4.11	+1.3	10	4,238	w.	19	nw?	10	5	9	15	6.3	15.3	2.0
Philadelphia	114	123	190	29.96	30.09	−.01	32.5	−1.4	54	4	39	15	24	26	20	28	21	65	4.57	+1.1	10	7,665	n.	34	e.	5	10	7	12	5.7	10.3	T.
Reading	325	81	98	29.72	30.09	-----	30.0	-----	46	3	36	12	24	24	18	27	23	77	4.20	+0.6	8	5,462	nw.	38	e.	20	12	5	12	5.2	14.1	0.4
Scranton	805	111	119	29.18	30.08	.00	25.7	−1.2	45	4	33	6	24	19	28	22	18	77	2.67	−0.2	10	5,360	nw.	30	ne.	20	4	10	15	7.1	15.0	1.5
Atlantic City	52	37	172	30.01	30.07	−.04	32.7	−0.9	53	5	38	15	13	27	19	29	25	76	4.05	+0.7	9	12,748	nw.	68	se.	20	13	6	10	5.1	12.8	0.0
Cape May	17	13	49	30.09	30.11	.00	33.6	−0.5	52	5	39	15	24	28	18	30	26	77	2.51	−0.9	9	6,749	nw.	46	se.	20	10	5	14	5.6	5.3	0.0
Sandy Hook	22	10	55	30.04	30.06	-----	29.6	-----	45	20	34	12	13	25	15	26	20	70	4.41	-----	11	12,599	w.	56	ne.	5	11	6	12	5.5	8.5	T.
Trenton	190	159	183	29.86	30.07	-----	29.6	-----	50	2	36	9	14	23	24	25	19	68	3.44	+0.1	12	8,739	nw.	44	e.	5	11	5	13	5.7	15.6	0.0
Baltimore	123	100	113	29.95	30.08	−0.3	34.6	−0.8	56	4	40	18	24	29	20	30	24	67	4.14	+0.5	8	4,594	w.	24	ne.	20	8	10	11	5.9	10.2	0.0
Washington	112	62	85	29.97	30.10	−0.1	34.2	−1.1	59	4	40	17	24	28	22	29	23	66	3.05	−0.5	8	5,712	nw.	33	nw.	15	8	10	11	6.0	4.9	0.0
Cape Henry	18	8	54	30.04	30.06	-----	39.6	-----	64	5	45	26	23	34	30	36	31	75	3.64	−0.2	10	11,168	nw.	62	n.	15	12	10	7	4.8	1.5	T.
Lynchburg	681	153	188	29.32	30.09	−.02	37.8	−2.5	68	4	46	22	23	30	34	31	24	63	1.87	−1.8	6	6,175	nw.	36	nw.	10	10	11	8	5.4	1.3	0.0
Norfolk	91	170	205	29.98	30.09	−.02	40.5	−2.2	68	4	48	25	16	33	25	35	28	66	3.15	−0.7	8	10,162	ne.	44	ne.	27	11	12	6	4.7	3.0	0.0
Richmond	144	11	52	29.94	30.10	−.01	38.2	−1.4	68	5	47	20	16	30	30	31	24	64	2.34	−0.9	8	6,307	ne.	34	nw.	10	12	8	9	5.3	T.	0.0
Wytheville	2,304	49	55	27.64	30.11	−.01	32.2	−2.9	60	4	39	14	9	26	28	28	24	77	2.00	−2.2	11	5,652	w.	30	sw.	11	6	7	16	7.0	7.6	T.
South Atlantic States							44.5	−3.4										71	3.19	−0.8										4.9		
Asheville	2,255	70	84	27.69	30.13	.00	35.8	−2.7	62	3	43	16	22	28	31	31	26	72	2.79	−0.5	11	7,557	nw.	31	n.	14	9	9	11	5.6	8.0	T.
Charlotte	779	55	62	29.23	30.09	−.03	40.6	−3.3	66	3	49	21	9	32	29	34	29	68	4.18	−0.3	11	4,430	ne.	24	w.	10	9	9	11	5.6	2.4	0.0
Hatteras	11	11	50	30.04	30.05	−.06	44.3	−3.1	64	5	51	28	10	38	23	40	37	78	6.15	+1.5	11	12,190	nw.	56	nw.	27	12	10	7	4.8	0.0	0.0
Manteo	12	5	42	-----	-----	-----	41.6	-----	66	4	---	21	10	---	32	-----	-----	-----	6.68	-----	8	-----	n.	--	-----	-----	-----	-----	-----	-----	0.0	0.0
Raleigh	376	103	110	29.68	30.10	−.01	40.6	−2.6	68	3	49	22	22	32	28	35	29	68	4.95	+0.5	9	6,513	nw.	32	nw.	10	10	9	10	5.2	2.4	0.0
Wilmington	78	81	91	30.00	30.10	−.02	46.1	−1.8	68	4	55	25	9	37	28	40	36	74	2.61	−0.9	9	5,544	w.	33	s.	20	15	7	7	4.2	0.0	0.0
Charleston	48	11	92	30.04	30.09	−.03	49.5	−2.9	73	18	57	29	9	42	25	43	37	70	1.57	−1.9	7	8,442	w.	38	ne.	26	13	5	11	4.7	0.0	0.0
Columbia, S. C	351	41	57	29.72	30.11	.00	44.5	−3.7	72	15	54	22	9	35	32	38	32	69	2.18	−2.5	8	5,403	ne.	35	sw.	5	14	5	10	4.8	T.	0.0
Due West	711	10	55	29.33	30.12	-----	41.6	-----	71	15	51	18	9	32	34	-----	-----	-----	3.54	-----	12	7,504	w.	37	ne.	26	10	7	12	5.4	0.4	0.0
Greenville, S. C	1,039	113	122	28.95	30.07	-----	41.5	−1.8	70	15	50	20	9	33	36	35	30	69	3.90	-----	11	6,760	ne.	35	ne.	26	14	4	11	4.9	T.	0.0
Augusta	180	62	77	29.90	30.10	−.02	46.0	−3.9	73	15	55	26	9	37	33	40	35	74	2.86	−1.6	10	4,349	nw.	27	sw.	5	12	7	10	4.9	0.0	0.0
Savannah	65	150	194	30.03	30.10	−.02	50.2	−3.8	76	18	59	28	9	42	27	43	37	70	1.92	−1.5	7	9,848	nw.	40	ne.	26	15	7	7	4.0	0.0	0.0
Jacksonville	43	209	245	30.05	30.10	−.02	54.6	−3.4	77	18	63	31	9	46	28	47	41	69	2.65	−0.9	9	9,346	w.	40	w.	5	12	9	8	4.5	0.0	0.0
Florida Peninsula							63.6	−3.6										74	1.84	−0.6										5.2		
Key West	22	10	64	30.07	30.09	+.02	67.6	−2.9	81	26	72	56	29	63	16	61	58	78	0.47	−1.2	5	9,239	n.	35	w.	26	9	13	7	5.0	0.0	0.0
Miami	25	71	79	30.09	30.12	-----	64.0	−4.8	79	5	72	42	10	56	27	57	53	72	1.69	−0.5	6	6,638	nw.	30	w.	29	12	6	11	5.3	0.0	0.0
Sand Key	23	39	72	30.08	30.11	+.01	67.4	-----	78	26	70	57	10	64	11	62	58	72	0.38	-----	3	13,549	n.	47	w.	26	8	14	7	5.3	0.0	0.0
Tampa	35	79	87	30.08	30.12	+.02	59.2	−3.1	79	18	67	38	10	51	29	52	48	74	3.35	0.0	9	4,488	w.	22	w.	1	10	10	9	5.1	0.0	0.0
East Gulf States							49.0	−2.3										70	4.52	−0.4										5.2		
Atlanta	1,174	190	216	28.84	30.10	−.02	42.2	−3.1	71	15	50	19	22	34	27	36	30	68	2.97	−1.8	11	9,459	nw.	42	e.	26	10	5	14	5.7	T.	0.0
Macon	370	78	87	29.71	30.11	−.01	46.2	−3.1	75	15	56	22	9	36	39	39	33	65	4.83	+0.1	9	4,913	nw.	30	se.	4	10	7	12	5.4	0.0	0.0
Thomasville	273	49	58	29.80	30.11	−.01	52.6	−2.4	78	18	62	28	9	43	31	44	39	69	4.31	−0.3	8	3,789	sw.	24	ne.	26	11	7	11	4.9	0.0	0.0
Apalachicola	36	42	49	30.07	30.11	-----	54.0	-----	72	14	61	34	9	47	25	48	45	77	5.27	-----	9	5,977	w.	31	ne.	26	12	10	7	4.3	0.0	0.0
Pensacola	56	149	185	30.05	30.11	.00	53.0	−2.2	72	14	60	34	9	46	21	48	44	75	3.34	−1.3	6	9,501	n.	46	sw.	4	10	7	12	5.3	0.0	0.0
Anniston	741	9	57	29.33	30.15	+.03	43.8	−2.0	73	15	54	17	9	34	40	-----	-----	-----	3.75	−1.0	12	4,517	nw.	23	e.	26	13	2	14	5.3	0.1	0.0
Birmingham	700	11	48	29.35	30.13	+.01	46.2	−1.8	75	15	55	24	22	37	31	39	32	64	5.89	+1.0	12	5,369	nw.	31	se.	4	12	4	13	5.2	T.	0.0
Mobile	57	125	161	30.05	30.11	.00	52.4	−2.8	71	14	61	31	6	44	24	47	43	76	4.37	−1.2	7	6,923	sw.	44	sw.	4	9	9	11	5.3	0.0	0.0
Montgomery	223	100	112	29.86	30.12	.00	49.4	−2.2	77	15	58	26	9	41	35	43	37	67	5.75	+0.1	8	5,113	nw.	24	e.	26	14	3	12	5.0	T.	0.0
Corinth	469	6	-----	-----	-----	-----	43.2	-----	76	15	52	20	6	34	38	-----	-----	-----	4.52	-----	16	-----	nw.	-----	-----	-----	7	11	11	-----	T.	0.0
Meridian	375	85	93	29.71	30.12	+.01	48.6	−1.0	76	15	58	26	6	39	37	42	36	67	5.16	+0.1	8	4,374	nw.	25	ne.	26	15	4	10	4.9	T.	0.0
Vicksburg	247	65	73	29.87	30.16	+.06	49.2	−2.6	76	15	57	24	6	41	29	42	36	66	3.79	−1.0	11	5,334	n.	29	w.	5	10	6	13	5.7	T.	0.0
New Orleans	53	76	84	30.06	30.12	+.03	55.2	−2.1	76	17	63	33	6	47	24	49	44	73	5.53	+1.0	9	4,838	s.	25	ne.	25	10	8	11	5.2	0.0	0.0
West Gulf States							49.5	−0.6										73	2.86	0.0										5.8		
Shreveport	249	77	93	29.88	30.16	+.07	49.0	−1.0	75	15	57	23	6	41	28	42	36	68	3.83	+0.1	10	4,973	nw.	29	w.	3	9	5	15	6.3	T.	0.0
Bentonville	1,303	11	44	-----	-----	-----	38.6	+0.1	73	14	48	2	6	29	34	-----	-----	-----	1.76	-----	8	3,938	nw.	25	nw.	20	11	6	12	-----	2.0	0.0
Fort Smith	457	79	94	29.64	30.13	+.03	42.2	−2.7	73	14	51	14	6	34	33	37	31	68	1.55	−1.3	9	6,037	e.	32	nw.	5	11	3	15	5.9	T.	0.0
Little Rock	357	136	144	29.74	30.13	+.02	44.1	−0.8	76	13	52	15	6	36	37	38	31	66	1.64	−2.7	9	6,849	n.	40	sw.	3	10	3	16	6.0	T.	0.0
Brownsville	57	53	61	30.04	30.10	-----	62.0	-----	86	3	71	35	27	53	28	55	52	79	0.87	-----	7	6,535	s.	33	nw.	25	12	12	6	4.5	0.0	0.0
Corpus Christi	20	11	73	30.11	30.13	+.08	58.0	+0.3	80	1	66	37	27	50	35	53	50	81	1.30	−0.8	7	9,659	s.	37	nw.	25	13	11	5	5.3	0.0	0.0
Dallas	512	109	117	29.60	30.16	-----	47.4	-----	78	2	56	23	6	38	33	-----	-----	-----	2.24	-----	8	6,089	nw.	40	nw.	4	4	10	14	6.2	7.5	0.0
Fort Worth	670	106	114	29.42	30.13	+.08	47.4	−0.7	80	2	57	23	5	38	35	41	35	68	1.97	+0.6	6	5,970	nw.	40	w.	4	10	5	14	5.9	0.0	0.0
Galveston	54	106	114	30.08	30.14	+.07	55.6	−0.7	72	1	61	35	5	50	22	51	49	84	5.67	+2.5	8	8,611	se.	42	nw.	4	12	9	8	4.6	0.0	0.0
Groesbeck	461	11	56	29.64	30.13	-----	48.7	-----	78	14	57	25	5	40	36	-----	-----	-----	4.08	-----	9	8,151	n.	38	n.	25	9	2	18	6.3	3.5	0.0
Houston	138	111	121	29.98	30.13	-----	55.4	+1.4	78	14	64	34	5	47	34	-----	-----	-----	4.87	-----	11	5,975	n.	30	nw.	4	9	8	12	5.7	0.0	0.0
Palestine	510	64	72	29.60	30.15	+.07	49.1	−2.1	78	14	57	26	6	41	34	44	36	70	3.97	+0.5	9	6,093	n.	30	nw.	4	9	4	16	6.5	T.	0.0
Port Arthur	34	58	66	30.08	30.13	+.12	54.9	-----	78	14	62	36	4	48	33	50	46	78	6.34	-----	10	7,043	se.	37	nw.	4	4	11	14	5.5	T.	0.0
San Antonio	693	119	132	29.39	30.16	+.08	54.4	0.0	81	1	64	32	25	44	35	47	41	68	3.02	+1.2	6	6,714	ne.	41	nw.	4	11	7	11	5.3	T.	0.0
Taylor	583	55	63	29.54	30.16	+.10	50.4	−0.9	79	14	59	29	5	42	38	-----	-----	-----	2.79	+0.1	9	6,707	w.	35	w.	4	8	6	15	6.4	3.8	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1924*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
Ohio Valley and Tennessee							**34.4**	**−1.6**										**74**	**2.62**	**−1.1**										**7.2**		
Chattanooga	762	189	213	29.29	30.13	.00	41.5	−2.6	71	15	49	20	22	34	37	35	28	63	4.02	−1.1	12	5,992	w.	29	se.	4	10	5	14	6.0	T.	0.0
Knoxville	996	102	111	29.02	30.10	−.02	40.2	−1.7	66	3	47	21	9	33	32	35	30	74	4.66	−0.4	12	4,677	ne.	29	sw.	5	4	4	21	7.8	2.0	0.0
Memphis	399	76	97	29.69	30.13	+.02	42.8	−1.5	74	15	50	20	6	36	32	38	32	69	2.52	−2.0	9	5,939	n.	41	sw.	4	13	5	11	5.1	T.	0.0
Nashville	546	168	191	29.54	30.14	+.02	38.8	−2.8	68	3	46	18	7	31	33	34	30	74	3.44	−1.0	11	6,853	nw.	40	se.	4	8	5	16	6.6	1.5	0.0
Lexington	989	193	230	29.02	30.13	+.02	33.4	−2.0	65	3	40	14	7	27	24				2.60	−0.7	10	10,129	sw.	38	sw.	5	3	6	20	7.8	3.0	0.0
Louisville	525	219	255	29.54	30.14	+.03	34.4	−2.8	67	3	41	14	7	28	26	30	25	68	1.46	−2.4	8	8,570	ne.	39	sw.	4	4	9	16	7.2	1.5	0.0
Evansville	431	139	175	29.66	30.14	+.03	35.6	−0.7	69	3	42	15	6	29	25	31	26	72	1.55	−1.6	9	8,569	nw.	32	sw.	5	3	13	13	6.8	2.0	0.0
Indianapolis	822	194	230	29.20	30.12	+.02	30.5	−0.6	60	3	37	13	22	24	28	28	24	80	1.44	−1.8	11	9,290	w.	38	nw.	9	1	13	15	7.4	3.6	0.0
Royal Center	736	11	55	29.29	30.13		26.6		50	3	33	4	22	20	29				1.36		8	8,025	e.	38	nw.	9	6	4	19	7.5	3.6	0.0
Terre Haute	575	96	129	29.49	30.13		31.8		62	3	38	11	7	25	24	28	25	77	1.89		10	7,583	nw.	31	nw.	10	3	11	15	7.1	2.9	0.0
Cincinnati	628	11	51	29.42	30.12	+.02	31.6	−1.2	61	3	38	15	22	25	26		25	78	1.70	−1.6	12	6,516	sw.	28	sw.	9	4	6	19	7.6	2.9	0.0
Columbus	824	179	222	29.20	30.11	+.02	30.2	−0.5	60	4	36	15	16	24	23	26	22	75	1.73	−1.4	14	8,326	w.	39	nw.	10	2	6	21	8.2	5.3	0.0
Dayton	899	137	173	29.12	30.11		30.4	+0.4	59	3	36	14	22	24	26	27	23	75	1.79	−1.4	14	7,938	ne.	36	nw.	10	3	8	18	7.4	2.6	0.0
Elkins	1,947	59	67	27.97	30.12	+.02	29.6	−2.0	66	4	38	−4	16	22	41	26	23	82	4.07	+0.8	17	4,244	w.	28	w.	10	0	9	20	8.3	15.2	T.
Parkersburg	638	77	84	29.44	30.12	+.02	33.4	−0.8	68	4	40	15	16	27	27	29	26	80	3.07	−0.3	11	4,366	sw.	30	nw.	10	4	6	19	7.7	7.0	0.0
Pittsburgh	842	353	410	29.16	30.10	+.01	29.3	−3.0	66	4	36	10	16	23	26	26	21	73	2.59	−0.2	13	8,099	w.	42	nw.	10	4	7	18	7.3	11.6	T.
Lower Lake Region							**22.1**	**−2.9**										**80**	**2.11**	**−0.4**										**6.9**		
Buffalo	767	247	280	29.23	30.10	+.04	21.4	−2.9	39	5	27	1	24	15	22	19	16	79	2.65	−0.3	19	12,829	w.	64	sw.	20	5	7	17	7.4	22.0	10.9
Canton	448	10	61	29.58	30.10		10.0	−8.0	35	27	19	−19	19	1	29				2.02	−0.6	10	7,538	w.	44	e.	5	13	7	9	4.6	20.5	16.5
Oswego	335	76	91		30.09	+.03	19.2	−4.7	34	2	26	−1	17	13	27			87	1.79	−0.9	12	8,066	s.	37	nw.	10	6	3	20		29.7	17.7
Rochester	523	86	102	29.51	30.10	+.04	21.0	−3.6	38	6	27	0	24	15	28	19	15	77	3.07	+0.2	16	6,159	w.	34	w.	21	6	2	21	7.5	29.4	12.5
Syracuse	597	97	113	29.42	30.09	+.02	19.3	−4.5	35	2	26	2	19	13	25				2.75	+0.9	16	7,483	w.	42	w.	10	6	5	18	7.2	21.0	8.8
Erie	714	130	166	29.29	30.09	+.02	23.4	−3.5	42	1	30	2	24	17	23	22	19	80	1.27	−1.7	15	9,136	sw.	62	se.	20	6	5	18	7.2	10.0	3.2
Cleveland	762	190	201	29.25	30.10	+.03	25.4	−2.0	48	5	30	8	24	20	20	24	20	81	1.50	−1.2	14	8,598	ne.	42	nw.	10	3	9	17	7.8	7.8	0.9
Sandusky	629	62	70	29.40	30.11	+.04	26.1	−1.3	41	5	31	10	24	22	20				1.67	−0.8	14	6,125	w.	43	nw.	10	2	10	17	7.5	10.0	T.
Toledo	628	208	243	29.41	30.12	+.05	25.8	−1.5	43	27	31	9	24	20	22	23	20	79	2.28	+0.2	13	10,555	sw.	45	w.	10	7	8	14	6.6	13.9	0.3
Fort Wayne	856	113	124	29.16	30.12		26.2	+0.4	47	1	32	6	22	20	22	24	20	80	1.23		10	7,164	e.	31	nw.	9	8	5	16	6.7	8.7	T.
Detroit	730	218	258	29.29	30.12	+.06	25.5	+0.2	45	27	31	9	24	20	24	23	19	78	2.06	−0.2	15	8,111	e.	38	e.	19	8	7	14	6.4	13.5	0.4
Upper Lake Region							**20.7**	**+1.6**										**84**	**1.60**	**−0.2**										**6.8**		
Alpena	609	13	92	29.44	30.14	+.11	16.4	−1.6	36	1	25	−12	24	7	39	16	12	82	1.62	−0.2	13	8,492	nw.	46	ne.	5	5	11	13	6.6	18.8	10.0
Escanaba	612	54	60	29.47	30.17	+.11	17.6	+2.2	37	10	26	−2	13	10	30	16	14	85	1.09	−0.3	6	6,876	n.	32	ne.	5	7	5	17	6.8	10.6	9.5
Grand Haven	632	54	89	29.41	30.13	+.08	23.3	−0.9	38	27	30	−2	23	17	27	21	17	77	2.19	+0.2	11	8,001	ne.	43	w.	9	7	7	15	6.7	15.5	2.8
Grand Rapids	707	70	87	29.34	30.14	+.09	24.0	−1.5	41	27	30	3	23	18	27	21	18	81	1.41	−0.6	12	4,739	e.	29	e.	4	3	10	16	7.2	9.0	1.0
Houghton	668	62	99	29.42	30.18	+.13	18.4	+4.7	43	26	26	−15	23	11	35				0.61	−1.2	11	7,049	w.	39	nw.	9	4	8	17	7.7	7.1	12.6
Lansing	878	11	62	29.13	30.11		22.1	+0.5	43	1	30	−8	24	14	36	19	17	86	2.13	0.0	12	4,340	ne.	21	nw.	10	8	8	13	6.4	15.6	0.5
Ludington	637	60	66	29.41	30.14		22.2		36	1	29	−5	24	16	30	21	18	85	2.46		10	7,202	e.	35	sw.	9	7	5	17	6.6	24.2	2.4
Marquette	734	77	111	29.36	30.20	+.15	21.0	+5.1	52	26	27	4	23	15	35	19	16	84	2.18	+0.4	18	7,189	nw.	27	nw.	21	4	4	21	8.0	21.8	15.5
Port Huron	638	70	120	29.38	30.10	+.05	21.8	−0.9	40	27	28	−3	24	15	28	21	19	86	1.62	−0.6	12	7,611	nw.	36	nw.	10	5	15	9	6.2	20.5	4.0
Saginaw	641	69	77	29.40	30.13		20.4		37	1	28	−9	24	13	28	19	16	86	2.17	0.0	11	5,879	nw.	31	ne.	5	7	6	16	6.8	17.7	7.9
Sault Sainte Marie	614	11	52	29.60	30.18	+.15	12.2	−0.4	38	27	21	−17	23	3	40	10	8	86	1.02	−0.4	10	5,418	se.	34	nw.	10	6	10	13	6.6	10.6	20.0
Chicago	823	140	310	29.22	30.14	+.06	28.8	+1.4	44	27	33	10	22	24	18	26	22	74	1.68	−0.6	7	8,685	nw.	45	ne.	4	6	4	19	7.2	7.9	T.
Green Bay	617	109	144	29.45	30.15	+.09	20.0	+2.8	37	14	27	−3	23	13	29	18	16	86	1.55	−0.1	8	8,378	n.	48	n.	4	6	3	20	7.2	16.2	9.0
Milwaukee	681	125	139	29.37	30.14	+.08	26.1	+3.3	41	26	31	7	22	21	19	24	21	84	2.52	+0.6	13	8,066	w.	37	e.	18	7	4	18	6.9	27.4	2.0
Duluth	1,133	11	47	28.93	30.21	+.13	17.7	+6.3	43	26	25	−9	5	10	31	15	13	88	0.60	−0.4	8	9,859	ne.	40	nw.	14	10	8	11	5.2	7.9	3.7
North Dakota							**20.6**	**+12.9**										**79**	**0.34**	**−0.2**										**5.8**		
Moorhead	940	50	58	29.17	30.24	+.12	17.8	+9.7	50	26	28	−17	21	8	36	15	11	77	0.35	−0.4	5	6,011	s.	29	nw.	9	16	2	11	4.6	3.2	0.0
Bismarck	1,674	8	57	28.38	30.25	+.13	24.5	+14.2	63	12	35	−12	21	14	41	20	16	75	0.28	−0.2	4	5,930	nw.	29	nw.	9	10	7	12	5.5	2.6	T
Devils Lake	1,478	11	44	28.57	30 23	+.12	16.4	+11.9	46	1	27	−19	23	6	41	14	11	85	0.39	−0.2	3	6,585	se.	28	n.	3	13	6	10	4.9	7.0	0.5
Ellendale	1,457	10	56	28.60	30.23		21.2		54	28	34	−13	21	9	42				0.38		5	9,477	nw.	52	n.	3	10	6	13	5.9	3.0	0.0
Grand Forks	835	12	89				15.2		44	13	26	−20	23	4	42				0.33		5		se.	34	nw.	9	16	4	9		4.2	0.7
Williston	1,878	41	48	28.12	30.18	+.07	23.8	+15.7	58	12	32	−13	20	15	32	21	18	78	0.34	−0.2	7	5,591	se.	30	w.	12	4	3	22	8.1	3.6	0.0
Upper Mississippi Valley							**28.0**	**+2.9**										**80**	**1.23**	**−0.6**										**5.8**		
Minneapolis	918	102	208	29.16	30.19		21.6		44	27	29	0	21	14	26				0.63	−0.1	8	8,154	nw.	40	n.	4	7	10	12	6.1	5.5	T.
St. Paul	837	236	261	29.25	30.19	+.10	21.2	+5.4	44	27	29	−2	22	14	27				0.58	−0.3	10	8,280	nw.	44	nw.	9	9	9	11	5.8	6.0	T.
La Crosse	714	11	48	29.36	30.17	+.09	23.2	+4.0	44	27	31	−7	22	15	36				0.93	−0.2	9	3,916	nw.	22	w.	9	7	8	14	6.2	10.6	T.
Madison	974	70	78	29.07	30.18	+.11	23.2	+4.1	40	26	29	2	22	17	23	21	18	82	1.06	−0.5	11	7,453	nw.	43	ne.	4	7	5	17	7.0	10.3	0.4
Wausau	1,247	4		28.78	30.19		18.2		42	27	26	−7	24	10	33				1.00		8		nw.				9	4	16	6.4	10.5	5.4
Charles City	1,015	10	49	29.06	30.19	+.09	22.4	+7.3	47	2	31	−8	22	14	40	20	18	87	1.14	+0.1	6	5,025	nw.	26	ne.	4	11	7	11	5.2	12.8	T.
Davenport	606	71	79	29.46	30.16	+.06	27.2	+2.3	54	2	34	5	22	20	24	25	23	86	1.46	−0.2	8	6,180	nw.	40	ne.	4	8	7	14	6.2	11.7	T.
Des Moines	861	84	97	29.22	30.16	+.05	27.2	+3.5	65	2	36	−4	25	19	36	25	22	83	1.98	+0.9	6	5,458	nw.	28	n.	4	12	4	13	5.2	19.3	0.5
Dubuque	700	81	96	29.40	30.16	+.10	25.7	+3.5	47	27	32	−2	22	19	32	23	19	78	0.74	−0.7	9	5,025	nw.	27	ne.	4	6	5	18	7.3	8.6	0.1
Keokuk	614	64	78	29.46	30.16	+.05	29.8	+1.5	62	3	37	2	7	22	27	23	21	73	0.93	−0.8	7	5,770	n.	27	nw.	9	14	2	13	4.9	12.0	0.0
Cairo	358	87	93	29.73	30.13	+.01	37.8	−0.7	69	3	45	15	6	30	29	33	27	69	1.47	−2.0	9	7,609	n.	37	n.	26	7	10	12	6.3	2.4	0.0
Peoria	609	11	45	29.46	30.15	+.05	28.0	+2.1	58	3	35	6	22	21	28	26	24	88	1.64	−1.1	11	5,284	ne.	28	ne.	4	14	3	12	5.2	5.9	0.0
Springfield, Ill.	636	10	91	29.41	30.12	+.02	31.0	+1.5	61	29	38	10	7	24	26	28	25	84	1.96	−0.9	10	6,138	w.	24	w.	9	13	4	12	5.2	7.3	T.
Hannibal	534	74	109	29.37	30.14	+.02	31.8	+2.1	64	3	39	3	8	24	29				1.35	−0.3	8	6,891	nw.	28	n.	4	14	4	11	5.0	8.6	0.0
St. Louis	568	265	303	29.50	30.13	+.02	35.6	+1.1	66	3	43	13	6	28	30	31	26	72	1.29	−1.6	8	9,143	nw.	35	nw.	20	14	5	10	5.0	2.3	0.0
Missouri Valley							**30.5**	**+4.7**										**76**	**1.09**	**0.0**										**4.8**		
Columbia, Mo.	784	11	84	29.27	30.13	+.02	32.7	+1.0	67	2	41	1	8	24	33				1.95	−0.3	9	6,480	w.	31	sw.	29	14	1	14	5.1	10.3	0.0
Kansas City	963	161	181	29.08	30.15	+.04	34.6	+3.4	69	2	43	3	6	26	28	30	25	72	1.16	−0.5	8	9,011	n.	48	n.	4	15	3	11	4.7	10.6	0.0
St. Joseph	967	11	49	29.07	30.14		32.5		71	2	41	3	6	24	32	28	24	78	1.70		8	6,553	nw.	35	nw.	4	15	4	10	4.5	11.4	0.0
Springfield, Mo.	1,324	98	104	28.69	30.14	+.03	36.4	+1.2	70	14	45	0	6	28	31	32	28	78	1.23	−1.2	8	7,519	nw.	34	w.	29	14	4	11	4.8	4.6	0.0
Iola	984	11	50	29.07	30.15	+.05	36.0	+4.0	70	14	46	3	6	26	37				1.18	0.0	6	5,191	n.	27	n.	4	15	5	9	4.8	7.3	0.0
Topeka	987	92	107				34.6	+3.6	72	2	44	0	6	25	34				0.94	−0.5	7	7,737	n.	45	n.	4	15	7	7	4.0	6.1	0.0
Drexel	1,299	10	54	28.72	30.16		27.8		63	13	38	−3	5	18	35				0.99		6	8,547	nw.	38	ne.	3	9	11	9	5.4	9.7	T.
Lincoln	1,189	11	84	28.80	30.18	+.08	30.6	+4.5	65	2	41	0	6	20	35	27	23	78	0.99	+0.2	9	7,676	n.	40	n.	3	10	8	11	5.7	7.1	0.0
Omaha	1,105	115	122	28.95	30.18	+.07	29.8	+4.3	62	2	38	−2	5	21	32	26	22	75	0.98	+0.2	8	6,779	nw.	44	n.	4	14	5	10	4.6	9.6	T.
Valentine	2,598	47	54	27.38	30.20	+.11	29.2	+7.8	62	12	40	−8	5	18	44	25	20	75	0.91	+0.3	7	6,732	w.	38	n.	3	13	7	8	4.6	7.3	T.
Sioux City	1,135	94	164	28.94	30.20	+.08	26.6	+5.6	59	2	35	−5	5	18	35	23	19	76	1.01	+0.4	7	7,631	nw.	44	nw.	9	13	8	7	4.9	9.7	T.
Huron	1,306	59	74	28.78	30.24	+.12	23.0	+8.7	56	2	33	−14	21	13	35	20	15	75	0.58	+0.1	8	6,678	se.	40	nw.	3	14	8	7	4.2	7.5	T.
Pierre	1,572	70	75	28.49	30.23	+.12	26.4	+7.8	62	1	37	−10	6	16	38	23	19	78	0.89	+0.4	8	5,647	nw.	39	n.	3	11	11	7	4.5	9.2	0.0
Yankton	1,233	49	57	28.83	30.21	+.09	25.9	+4.9	66	2	35	−9	5	17	41				1.22	+0.6	7	5,752	nw.	31	n.	3	11	7	11	5.5	13.4	T.

TABLE 1.—*Climatological data for Weather Bureau stations, February, 1924*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0-10	In.	In.
Northern Slope							**30.3**	**+8.6**										**72**	**0.64**	**-0.2**										**5.9**		
Billings	3,140	5					35.9		65	12	48	-16	20	24	48				0.29		4						14	6	9		4.5	0.0
Havre	2,505	11	44	27.44	30.16	+.09	29.4	+15.8	63	12	39	-14	20	20	32	26	23	79	0.43	-0.1	6	5,597	sw.	46	sw.	12	6	10	13	6.2	4.3	0.0
Helena	4,110	87	112	25.89	30.19	+.09	34.1	+11.1	61	12	43	-7	20	25	31	29	22	63	0.45	-0.3	5	5,887	sw.	54	sw.	12	6	7	16	6.8	7.3	0.0
Kalispell	2,973	48	56	27.04	30.18	+.10	33.0	+9.7	54	12	40	11	10	26	23	30	27	78	0.51	-1.0	11	2,696	nw.	25	sw.	28	6	5	18	6.9	2.1	0.0
Miles City	2,371	48	55	27.61	30.25	+.16	30.0	+13.2	57	12	38	3	19	22	34	27	23	78	0.91	+0.3	8	3,795	nw.	27	nw.	8	10	5	14	6.1	6.7	0.0
Rapid City	3,259	50	58	26.70	30.24	+.16	30.0	+7.6	65	1	40	-2	20	20	40	25	19	66	0.96	+0.5	7	5,837	w.	44	nw.	29	9	10	10	5.5	9.5	0.0
Cheyenne	6,088	84	101	24.03	30.17	+.14	31.6	+4.3	64	14	42	-1	20	21	36	26	20	67	1.14	+0.6	7	10,336	w.	48	n.	3	6	12	11	5.9	14.3	T.
Lander	5,372	60	68	24.73	30.27	+.19	25.8	+3.3	49	28	36	-2	20	16	33	21	15	68	0.21	-0.5	3	2,304	sw.	36	w.	28	9	13	7	5.1	2.1	T.
Sheridan	3,790	10	47	26.20	30.24		28.1		54	13	39	-15	20	17	42	25	21	77	1.09		9	3,503	nw.	36	nw.	28	10	7	12	5.9	5.4	T.
Yellowstone Park	6,200	11	48	23.96	30.27	+.17	26.2	+6.6	51	14	36	-4	20	16	34	23	18	71	0.77	-1.1	14	4,979	s.	31	s.	1	7	14	8	5.7	7.1	7.0
North Platte	2,821	11	51	27.19	30.22	+.15	32.4	+5.8	68	2	44	-1	5	21	40	26	21	71	0.36	-0.1	5	5,502	n.	42	n.	3	15	2	12	4.8	2.7	0.0
Middle Slope							**37.4**	**+3.7**										**65**	**0.41**	**-0.4**										**4.9**		
Denver	5,292	106	113	24.78	30.16	+.15	37.6	+4.9	71	14	48	6	21	27	43	30	22	60	0.27	-0.2	3	5,843	s.	48	nw.	3	13	11	5	4.3	4.6	0.0
Pueblo	4,685	80	86	25.34	30.12	+.12	38.8	+5.9	76	14	53	13	5	25	46	30	21	55	0.12	-0.4	2	4,535	se.	52	w.	2	12	13	4	4.4	1.2	0.0
Concordia	1,392	50	58	28.64	30.17	+.08	34.2	+4.4	69	2	44	4	6	24	36	28	22	69	0.26	-0.5	5	6,372	nw.	32	nw.	4	12	6	11	5.1	1.0	0.0
Dodge City	2,509	11	51	27.52	30.20	+.14	35.9	+2.7	77	14	48	2	21	24	39	30	24	74	0.71	0.0	6	7,109	nw.	47	nw.	4	17	2	10	4.2	8.7	0.0
Wichita	1,358	139	158	28.67	30.14	+.06	37.4	+3.0	73	2	47	8	6	28	32	32	25	67	0.58	-0.5	5	9,306	n.	42	n.	4	11	10	8	4.8	1.0	0.0
Broken Arrow	765	11	52	29.29	30.14		39.8		73	14	49	9	6	31	34				1.15		6	9,143	n.	48	nw.	4	10	6	13	6.0	3.0	0.0
Muskogee	652	4					41.8		77	14	52	10	6	31	44				1.50		8		se.				10	9	10		3.3	0.0
Oklahoma City	1,214	10	47	28.85	30.17	+.10	40.7	+1.1	76	14	50	12	5	31	33	34	27	63	0.54	-0.5	4	7,174	n.	40	nw.	4	11	4	14	5.8	0.7	0.0
Southern Slope							**45.7**	**+0.6**										**62**	**1.07**	**+0.2**										**4.8**		
Abilene	1,738	10	52	28.31	30.16	+.11	45.5	+0.7	79	2	56	22	5	35	38	38	30	64	1.51	+0.4	6	6,599	n.	46	nw.	3	8	7	14	6.3	5.0	0.0
Amarillo	3,676	10	49	26.36	30.17	+.15	40.6	+3.4	74	13	52	21	5	29	40	34	29	73	0.56	-0.4	4	7,298	n.	50	nw.	3	16	7	6	4.4	2.7	0.0
Del Rio	944	64	71	29.12	30.13	+.13	53.4	-2.6	80	3	64	29	27	43	36				1.45	+0.5	7	6,236	se.	46	n.	3	16	2	11	4.7	3.2	0.0
Roswell	3,566	75	85	26.44	30.11	+.13	43.2	+0.7	76	2	58	18	5	29	48	34	21	50	0.76	+0.2	4	5,308	s.	44	nw.	3	17	7	5	3.7	5.0	0.0
Southern Plateau							**48.7**	**+3.9**										**42**	**0.08**	**-0.6**										**2.1**		
El Paso	3,762	110	133	26.25	30.06	+.11	48.9	0.0	73	8	62	26	5	36	37	38	22	41	0.13	-0.3	2	6,374	nw.	40	e.	24	21	5	3	2.5	T.	0.0
Santa Fe	7,013	38	53	23.25	30.09	+.11	35.4	+2.3	60	13	47	13	4	24	36	28	18	53	0.24	-0.6	5	4,882	n.	30	n.	3	15	9	5	3.6	1.8	0.0
Flagstaff	6,907	10	59	23.39	30.05	+.14	36.9	+6.1	60	19	51	14	4	22	38	29		56	0.08		2		w.	56	ne.	24	23	6	0		0.8	0.0
Phoenix	1,108	11	81	28.88	30.05	+.06	58.8	+3.7	82	13	75	32	4	43	39	45	30	39	T.	-0.7	0	3,377	e.	21	n.	13	23	6	0	1.3	0.0	0.0
Yuma	141	9	54	29.90	30.05	+.05	61.7	+3.1	85	19	78	40	2	46	42	47	29	33	0.00	-0.6	0	3,941	n.	30	nw.	24	26	3	0	0.8	0.0	0.0
Independence	3,957	5	25	26.11	30.18	+.12	50.4	+8.2	75	13	66	27	12	35	45	37	16	29	0.03	-0.8	1	5,663	nw.	46	n.	23	20	8	1	2.2	0.0	0.0
Middle Plateau							**39.6**	**+6.8**										**57**	**0.41**	**-0.7**										**4.8**		
Reno	4,532	74	81	25.60	30.20	+.12	43.5	+7.9	70	13	58	22	22	29	42	36	26	55	0.52	-0.8	4	3,274	w.	39	w.	25	11	10	8	4.8	0.1	0.0
Tonopah	6,090	12	20				41.6		64	13	50	22	3	33	26	32	19	43	0.12		1		w.								0.0	0.0
Winnemucca	4,344	18	56	25.77	30.23	+.14	39.9	+6.4	65	14	53	18	22	27	37	34	26	65	0.57	-0.4	7	3,909	sw.	34	nw.	1	8	10	11	5.8	0.2	0.0
Modena	5,479	10	43	24.72	30.15	+.11	37.3	+6.3	63	20	53	14	12	22	44	29	16	48	0.09	-1.2	3	6,355	w.	38	n.	21	17	8	4	3.4	0.2	0.0
Salt Lake City	4,360	163	203	25.76	30.22	+.14	39.2	+5.4	61	15	47	23	1	32	24	34	28	69	0.78	-0.7	5	3,618	nw.	28	nw.	21	10	8	11	5.6	6.6	0.0
Grand Junction	4,602	60	68	25.51	30.16	+.12	38.3	+5.4	60	13	50	18	1	27	32	31	23	62	0.09	-0.6	3	3,033	se.	22	nw.	2	10	11	8	4.4	T	0.0
Northern Plateau							**41.3**	**+8.5**										**70**	**1.33**	**-0.1**										**6.7**		
Baker	3,471	48	53	26.60	30.25	+.13	37.4	+9.5	52	14	45	21	10	30	23	34	29	72	1.25	-0.1	14	3,883	se.	19	se.	11	4	12	13	6.7	1.4	0.0
Boise	2,739	78	86	27.34	30.25	+.13	42.0	+7.2	61	14	51	29	3	33	29	37	30	64	1.13	-0.3	13	3,349	se.	31	w.	1	9	9	11	5.7	T.	0.0
Lewiston	757	40	48	29.39	30.21	+.10	45.0	+8.0	65	12	54	27	10	36	27				1.83	+0.4	12	2,669	e.	24	w.	25	3	9	17	7.5	0.0	0.0
Pocatello	4,477	60	68	25.61	30.23	+.13	36.5	+7.6	57	14	44	18	3	29	29	32	26	70	0.24	-0.6	5	6,025	se.	38	sw.	2	7	10	12	6.2	1.5	0.0
Spokane	1,929	101	110	28.11	30.20	+.11	40.7	+9.4	58	12	48	26	9	34	23	37	33	73	1.57	-0.4	12	4,273	sw.	27	sw.	12	3	11	15	7.2	1.3	0.0
Walla Walla	991	57	65	29.11	30.20	+.09	46.4	+9.3	66	11	54	29	9	39	24	42	37	70	1.96	+0.3	16	3,532	s.	27	w.	28	5	12	12	6.8	0.0	0.0
North Pacific Coast Region							**46.9**	**+5.0**										**85**	**6.27**	**+0.9**										**8.0**		
North Head	211	11	56	29.91	30.15	+.09	47.3	+4.3	60	19	51	39	8	44	19	45	43	87	8.30	+2.3	24	13,025	s.	74	s.	16	5	7	17	7.3	0.0	0.0
Port Angeles	29	8	53		30.12		43.6		57	27	49	32	8	38	17				4.25	+1.1	18	3,713	s.	31	nw.	27	0	7	22		0.0	0.0
Seattle	125	215	250	30.04	30.17	+.11	46.0	+4.9	57	27	51	30	9	41	19	43	40	81	5.66	+1.8	20	6,839	s.	37	sw.	27	0	6	23	8.1	0.0	0.0
Tacoma	213	113	120	29.94	30.15	+.09	46.1	+5.6	60	11	52	29	9	41	21				5.39	+0.1	20	4,402	s.	37	sw.	27	0	8	21	8.3	0.0	0.0
Tatoosh Island	86	9	57	29.99	30.09	+.09	45.7	+4.8	55	19	49	38	15	43	10	45	43	92	13.21	+4.2	28	14,170	e.	68	s.	4	2	7	20	8.3	0.0	0.0
Yakima	1,071	5					41.5		63	11	53	21	10	30	36				0.57		8		nw.				5	11	13	6.4	T.	0.0
Medford	1,425	4					44.4		64	12	54	28	10	35	33				2.23		11		se.				3	4	22		0.0	0.0
Portland, Oreg.	153	68	106	30.03	30.19	+.11	48.0	+5.9	64	11	54	32	16	42	20	46	43	83	5.21	-0.4	19	3,905	se.	24	sw.	1	0	5	24	8.9	0.0	0.0
Roseburg	510	9	57	29.67	30.23	+.13	48.1	+4.7	69	11	56	34	16	40	27	45	42	80	1.89	-2.8	19	1,547	s.	24	sw.	1	0	15	14	7.0	0.0	0.0
Middle Pacific Coast Region							**54.1**	**+4.3**										**75**	**2.25**	**-1.9**										**5.3**		
Eureka	62	73	89	30.18	30.25	+.14	50.3	+3.1	61	6	56	37	10	44	20	48	46	89	3.19	-4.1	13	3,075	se.	30	sw.	1	2	5	22	8.1	0.0	0.0
Point Reyes	490	7	18	29.64	30.15		52.6	+3.4	72	13	57	45	14	48	23				4.10		4	13,571	nw.	58	nw.	27	9	10	10	5.3	0.0	0.0
Red Bluff	332	50	56	29.82	30.19	+.08	55.0	+5.6	76	28	65	35	2	45	31	48	40	62	2.14	-1.6	5	3,589	nw.	23	se.	7	16	7	6	4.3	0.0	0.0
Sacramento	69	106	117	30.11	30.18	+.09	55.2	+5.1	73	28	64	39	3	46	26	51	45	72	2.00	-1.2	4	4,367	nw.	28	nw.	23	14	10	5	3.9	0.0	0.0
San Francisco	155	208	243	30.02	30.19	+.09	57.0	+4.8	73	28	64	46	3	50	22	51	47	76	3.30	-0.5	6	4,356	w.	23	w.	9	12	8	9	5.0	0.0	0.0
San Jose	141	12	110	30.04	30.19		54.4	+3.8	77	29	66	35	10	42	36				0.62	-2.0	4	3,479	nw.	23	nw.	26	11	9	9	5.0	0.0	0.0
South Pacific Coast Region							**59.4**	**+5.6**										**61**	**0.20**	**-2.4**										**3.0**		
Fresno	327	89	98	29.81	30.18	+.10	56.4	+5.3	79	14	68	36	3	45	32	49	42	64	0.31	-1.1	2	3,782	nw.	29	nw.	23	18	7	4	3.1	0.0	0.0
Los Angeles	338	159	191	29.73	30.10	+.04	62.6	+7.1	89	13	73	46	21	52	29	51	42	57	0.03	-3.0	1	3,603	sw.	24	n.	23	18	11	0	2.8	0.0	0.0
San Diego	87	62	70	30.00	30.09	+.03	59.0	+3.9	82	13	68	43	1	50	29	51	45	66	T.	-2.0	0	3,731	nw.	29	s.	14	16	11	2	3.0	0.0	0.0
San Luis Obispo	201	32	40	29.94	30.16	+.05	59.4	+6.3	87	13	71	38	25	48	38	49	40	56	0.44	-3.3	2	3,266	n.	22	ne.	17	18	7	4	3.2	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.96	30.05		74.2	-0.7	83	28	79	65	9	70	15				4.73	+2.1	22	9,342	e.	42	e.	17	8	12	9	5.9	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.76	29.89	.00	80.0	-0.3	92	6	88	64	5	71	23	71	69	82	0.05	-0.8	2	7,494	nw.	32	n.	21	8	19	2	4.5	0.0	0.0
Colon	36	7	97	29.87	29.91	.00	80.1	+0.1	86	21	85	69	4	76	16	74	72	80	2.80	+1.2	17	10,835	n.	31	n.	14	9	14	6	5.3	0.0	0.0
Alaska																																
Juneau	80	11	54				32.8		45	23	36	11	15	29	12	30	26	78	7.20		24	7,406	se.	34	se.	8	3	1	25	9.0	36.4	T.

TABLE II.—*Data furnished by the Canadian Meteorological Service, February, 1924*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Mean maximum	Temperature of the air: Mean minimum	Temperature of the air: Highest	Temperature of the air: Lowest	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Total snowfall
	Feet	*In.*	*In*	*In.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*In.*	*In.*	*In.*
St. Johns, N. F	125												
Sydney, C. B. I	48	29.83	29.88	−.04	16.2	−3.1	25.9	6.6	40	−10	5.53	+1.44	37.5
Halifax, N. S	88	29.81	29.92	−.03	20.5	−1.9	29.0	11.9	45	−1	1.81	−3.35	14.7
Yarmouth, N. S	65	29.83	29.91	−.08	23.6	−2.2	29.7	17.5	40	10	1.87	−2.87	17.0
Charlottetown, P. E. I	38	29.86	29.90	−.05	14.7	−2.9	22.1	7.4	40	−8	2.15	−0.91	21.5
Chatham, N. B	28	29.84	29.88	−.08	9.5	−3.0	21.8	−2.7	41	−22	1.24	−1.92	12.4
Father Point, Que	20	29.98	30.01	+.03	5.0	−6.5	12.9	−2.9	29	−18	1.56	−0.65	15.6
Quebec, Que	296	29.73	30.07	+.08	8.3	−3.5	15.6	1.0	34	−8	2.59	−0.68	25.9
Montreal, Que	187	29.86	30.09	+.07	11.4	−3.1	17.8	4.9	34	−5	2.64	−0.43	26.4
Stonecliffe, Ont	489												
Ottawa, Ont	236	29.84	30.13	+.11	11.4	−0.3	22.3	0.5	36	−11	2.57	−0.12	25.7
Kingston, Ont	285	29.77	30.11	+.07	14.5	−3.3	22.2	6.9	32	−8	1.05	−1.49	10.5
Toronto, Ont	379	29.68	30.11	+.07	20.2	−1.3	27.6	12.9	39	−2	3.26	+0.65	32.3
Cochrane, Ont	930				3.0		12.4	−6.4	39	−25	0.70		7.0
White River, Ont	1,244	28.78	30.18	+.16	3.1	+2.9	17.8	−11.5	38	−41	1.08	−0.44	10.8
Port Stanley, Ont	592	29.45	30.12	+.06	20.6	−2.2	28.9	12.4	39	−10	2.17	−1.04	16.8
Southampton, Ont	656	29.35			16.5	−3.4	24.7	8.3	34	−8	2.09	−0.81	20.9
Parry Sound, Ont	688	29.38	30.13	+.12	10.7	−3.6	20.9	0.5	33	−17	3.01	+0.09	30.1
Port Arthur, Ont	644	29.48	30.23	+.18	13.2	+6.8	21.8	4.6	42	−15	0.28	−0.62	2.8
Winnipeg, Man	760												
Minnedosa, Man	1,690	28.32	30.24	+.15	10.7	+13.4	21.1	0.3	41	−27	0.44	−0.17	4.4
Le Pas, Man	860				8.4		19.2	−2.3	43	−35	0.27		2.7
Qu'Appelle, Sask	2,115	27.81	30.15	+.07	18.6	+19.2	27.5	9.8	49	−12	0.76	+0.03	7.4
Medicine Hat, Alb	2,144												
Moose Jaw, Sask	1,759				21.1		29.5	12.8	55	−20	0.82		7.8
Swift Current, Sask	2,392	27.47	30.19	+.12	24.5	+16.5	33.9	15.2	57	−22	0.51	−0.23	5.1
Calgary, Alb	3,428												
Banff, Alb	4,521												
Edmonton, Alb	2,150												
Prince Albert, Sask	1,450	28.56	30.22	+.13	14.0	+17.0	25.2	2.7	47	−26	0.30	−0.39	3.0
Battleford, Sask	1,592	28.34	30.16	+.07	16.6	+16.5	27.3	6.0	48	−26	0.66	+0.29	6.6
Kamloops, B. C	1,262												
Victoria, B. C	230	29.86	30.12	+.12	45.1	+5.6	49.4	40.9	53	35	5.29	+1.19	0.0
Barkerville, B. C	4,180												

LATE REPORTS, JANUARY, 1924

Point Stanley, Ont	592	29.50	30.17	+.10	21.0	+1.2	28.4	13.6	44	−11	4.15	+1.16	15.8
Winnipeg, Man	760	29.24	30.14	+.03	−3.5	+3.3	4.8	−11.9	38	−31	0.42	−0.46	4.2
Qu'Appelle, Sask	2,115	27.70	30.11	+.03	−1.1	+2.7	8.8	−11.0	41	−34	0.76	+0.26	7.6
Swift Current, Sask	2,392	27.42	30.20	+.11	5.7	+2.6	15.2	−3.9	48	−36	0.42	−0.22	3.2
Prince Albert, Sask	1,450	28.48	30.17	+.08	−4.0	+4.4	5.6	−13.7	39	−36	0.59	−0.38	5.9
Battleford, Sask	1,592	28.28	30.15	+.07	−0.5	+5.4	9.7	−10.7	47	−40	0.42	+0.02	4.2

SEISMOLOGICAL REPORTS FOR FEBRUARY, 1924

W. J. HUMPHREYS, Professor in Charge

[Weather Bureau, Washington, April 3, 1924]

TABLE 1.—*Noninstrumental earthquake reports, February, 1924*

Day	Approximate time, Greenwich civil	Station	Approximate latitude	Approximate longitude	Intensity Rossi-Forel	Number of shocks	Duration	Sounds	Remarks	Observer
1924	*H. m.*	CALIFORNIA	° ′	° ′			*Sec.*			
Mch 9	11 40	Santa Clara	37 15	121 55	1		240	None	Felt by one	University of Santa Clara.
13	9 10	Calexico	32 41	115 30	2	2	2		Felt by several	F. C. Cihak.
		SOUTH CAROLINA								
14	16 06	Summerville	33 05	80 15		2		Loud	Felt by many	E. G. Robertson.
		WASHINGTON								
10	14 05	Seattle	47 38	122 20	2	2	10	None	do	Mrs. M. B. Summers.

TABLE 2.—*Instrumental seismological reports, February, 1924*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International. [For significance of symbols and description of stations, see REVIEW for January, 1924]

Date	Character	Phase	Time	Period T	Amplitude A_E	Amplitude A_N	Distance	Remarks
ALASKA.	*U. S. C. & G. S. Magnetic Observatory, Sitka*							
1924			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 24		P_N?	5 48 00	5				No definite M.
		S_N	5 50 39					
		e_E	5 51 10	12	*100			
		L_N	5 51 38	14		*100		
		F	6 09 ..					

* Trace amplitude.

Date	Character	Phase	Time	Period T	Amplitude A_E	Amplitude A_N	Distance	Remarks
CALIFORNIA.	*Theosophical University, Point Loma*							
1924			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 5			15 00 00		50	100		Tremors during preceding 24 hours.
24			15 00 00		100	200		
DISTRICT OF COLUMBIA.	*U. S. Weather Bureau, Washington*							
1924			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 24		e	5 58 36					
		L	6 08 45					
		F	6 30 *ca*					
HAWAII.	*U. S. C. & G. S. Magnetic Observatory, Honolulu*							
1924			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 16		e_E	0 37 17					
		e_N	0 36 25					
		F_E	0 45 ..					
		F_N	0 50 ..					
21		e_E	13 30 ..	10				Heavy micros.
		e_N	13 30 00	9				
		M_N	13 32 03	7		20		
		F	13 35 ..					
24		e_N	5 58 49					EW component out of order.
		M_N	6 02 15	8		60		
		C_N	6 05 00					
		F	6 16 ..					
ILLINOIS.	*U. S. Weather Bureau, Chicago*							
1924			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 11		e	7 17 00					Possibly not seismic.
		L	7 38 ..	18				
		L	7 41 ..	16				
		F	7 52 ..					
18		e	17 27 00					
		L?	17 51 40					
		L	17 56 30	16				
		F	18 10 *ca*					
19		e	7 23 20					
		L	7 52 30	18				
		F	8 40 *ca*					
21		eL	13 33 ..					
		F	13 45 *ca*					
22		e	11 01 44					Doubtful as to being seismic.
		F	11 20 *ca*					
24		P	(5 51)..					Time mechanism out of order.
		S	(5 56)..					
		L	(6 03 20)	16				
		F	7 20 *ca*					
26		e	12 29 *ca*					
		F	12 45 *ca*					
29		e	9 45 ..					
		F	10 20 *ca*					
CANAL ZONE.	*Panama Canal, Balboa Heights*							
1924			*H. m. s.*	*Sec.*	μ	μ	*Miles*	
Feb. 7		P_E	17 11 16				160 *ca*	Direction unknown.
		P_N	17 11 14					
		S_E	17 11 46					
		S_N	17 11 42					
		L_E	17 11 48					
		L_N	17 11 50					
		M_E	17 11 48		*19,000			
		M_N	17 11 52			*400		
		F_E	17 12 24					
		F_N	17 12 12					
CANAL ZONE.	*Panama Canal, Balboa Heights*—Continued							
1924			*H. m. s.*	*Sec.*	μ	μ	*Miles*	
Feb. 22		P_E	8 08 57				45 *ca.*	Direction unknown.
		P_N	8 08 47					
		L_E	8 09 05					
		L_N	8 08 56					
		M_E	8 09 08		*3,100			
		M_N	8 08 59			*3,000		
		F_E	8 11 03					
		F_N	8 11 13					

*Trace amplitude.

Date	Character	Phase	Time	Period T	Amplitude A_E	Amplitude A_N	Distance	Remarks
CANADA.	*Dominion Observatory, Ottawa*							
1924			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Feb. 9		eL17	23 50 ..					Very faint; sinusoidal L waves.
		L17	23 51 30	19				
		F	23 57 *ca*					
11		O	(6 13 30)				(14, 200)	Beyond tables. eP and eS indistinct. Micros.
		eP17	6 29 39					
			or 29 09					
		eS17	6 43 18					
			or 43 36					
		eL17	7 09 30					
		L17	7 23 ..	20	3.5			
		L17	7 36 ..	19	2.5			
		F	8 10 ..					
13		e17	23 29 18					
		(eL17)	23 49 ..					
		L17	23 59 ..	25	4.5			
14		L17	0 15 ..	18	2			Sinusoidal.
		L17	0 42 ..	18	2			
		F	1 10 ..					
14		eL	8 04 00	15	1			
		F	8 09 ..					
15		e	13 27 ..					Faint and irregular; No. 17 EW only.
		F	13 32 ..					
16		O	0 32 56				10,040	Faint.
		eP17	0 46 00					
		eS17	0 57 00					
		eL17	1 17 ..	30				Very small.
		L17	1 25 ..	19	1.5			
		F	1 50 ..					
17		e17	20 41 24					
		(eL17)	21 08 ..					
		L17	21 30 ..	14	1			
		F	21 45 ..					
18		e17	17 26 ..					
		(eL)	17 42 30					Sinusoidal.
		L	17 52 ..	15	2			
		F	18 25 ..					
19		i17	7 22 27					
		e17	7 26 30					
		(eL17)	7 33 30					
		L17	7 54 ..	15	1.5			
		L17	8 13 ..	22				Small.
		F	8 40 ..					
21		$e(L)_N$	13 35 ..					Small irregular traces in heavy micros.
		L_{EV}	13 40 ..	14				
22		e	11 11 ..					Faint and irregular; No. 17 only.
		F	11 20 ..					
24		O	(5 41 01)				(6, 080)	
		eP?	5 50 36					
		$ePR2_N$	5 53 39					Irregular L waves; phases difficult. On all three components.
		eS	5 58 16					
		SR1	6 02 48					
		eL	(6 07)..					
		M_N	6 08 12	12	14			
		L_N	6 10 ..	8	4			
		L_N	6 24 ..	8	1			
		F	6 52 ..					
26		e	12 29 12					Irregular L waves; short period small amplitudes.
		eL	12 31 ..					
		F	12 40 ..					
29		(e)17	9 01 ..					
		eL17	9 40 ..					
		L17	9 55 ..	18				Very small.
		F	10 10 ..					

TABLE 2.—*Instrumental seismological reports, February, 1924*—Continued

CANADA. *Meteorological Service of Canada, Toronto*

			H. m. s.	Sec.	μ	μ	Km.	
1924. Feb. 11		eP	6 29 30					
		e	6 43 21					
		S	6 43 35					
		eL	7 19 23					P poorly defined.
		L	(7 21 00)					
			(7 21 15)					
W		L	7 24 53	26				Small amplitude. Sinusoidal.
			7 32 17					
			7 34 38	17				
		eL	7 37 18	22				Small micros.
		F	8 12 --					
		iP	6 28 53					
		e	6 44 45					S not distinguishable.
N		eL	7 28 05	30				
		L	7 32 00					Sinusoidal. Small amplitude. Distant quake.
		L	7 38 23					
		F						Doubtful.
13		L	23 49 00					
W		L	0 01 07	23				
		L	0 14 30					
		F	1 17 00					
		e?	23 40 23					
		L	0 00 30					
N		L	0 09 15					Micros going on.
		F	1 08 --					
14		e	8 03 00					May not be seismic.
W		e	8 03 15	15				
		F						Micros.
		L	8 00 30					Slow waves mixed micros.
		L	8 04 30					
N		L	8 32 15					
		L	8 42 00					
		F						Micros.
15		e	5 04 08					May not be seismic.
W		F	5 06 --					
		L	5 04 25					
N		F	5 05 43					Mixed with micros.
16		i	0 44 15					Small amplitude micros and wind effect the boom.
		e	0 45 52					
		e	0 57 15					
		L	1 03 35					
W		L	1 24 28					
			1 33 00					Small sinusoidal.
		F	2 00 00					
		i	0 42 55					This component very little effected.
		e	0 52 02					
N		L	1 03 38					
		F	1 54 00					
17		e	0 22 23					May not be seismic.
W		F	0 25 00					N-S component does not show any movement.
17		L	21 22 00					Wind and micros effect the boom.
W		L	21 26 15					
		F?	21 50 00					N-S component barely effected.
18		i	17 26 23					
N		L	17 54 05	15				Very small amp.
		F						Micros.
		i	17 26 23					Sinusoidal.
			17 52 45					
		L	17 55 30	15		4		Constant small micros going on.
W		F	18 28 00					
19		i	7 22 55	10				Undulatory curves caused by high wind before 7 22 55.
		i	(7 23 20)					
			(7 23 23)					
W		e	7 32 38					
		L	7 33 15					
		L	?7 55 15					Micros and wind.
		i	7 22 56	4				
		i	7 23 00					The impetus is the most conspicuous on the curves.
		i	7 23 17					
		L	7 45 15					
N		L	7 55 15	22				
		L	8 10 23					
		L?	?9 05 00					
		F?	?9 40 00					
21		L?	13 38 15	8	15			Heavy micros going on.
W		L	13 40 00					Sinusoidal small waves.
		F						Micros.
		e	13 32 46					
N		L	13 36 15	15	6			Small micros going on.
			13 37 32	10				
		F						Micros.
22		L	11 14 08	15		6		Micros and heavy wind effect boom.

CANADA. *Meteorological Service of Canada, Toronto*—Continued

			H. m. s.	Sec.	μ	μ	Km.	
1924. W		F						Micros.
		L	11 10 38					
				11	3			Small micros mask early phases.
N			11 15 00					
		F	11 24 --					Sinusoidal.
24		eP	5 48 17					
		ePR	5 52 10					
		i	5 53 19					
W		eS	5 57 44					
		iS	5 57 53				8,050	
			6 02 38					No record, lights off.
			13 08 44					
		e	5 48 54					Only slightly shown.
N		S	5 57 52					
26		i	12 28 53	6				
		iL	12 31 08	15				
		L	12 34 00					Small amplitude.
W		eL	12 48 24					Irregular.
		L	12 54 02					
		F	12 58 --					
		e	12 29 25					
N		i	12 31 08					Very small amp.
		i	13 34 00	8				
		eL	12 50 45					
		eL	12 53 45					
		F	13 00 00					
29		e	9 00 51					
W		i	9 01 04					Small amplitude.
		eS?	9 11 51					
		eL	9 53 23	21				Disturbance in midst of tremor storm.
			9 54 00					
		F	?10 12 --					
		i	9 01 11					
		i	9 01 15					Do.
N		eL	9 45 38					
		F	10 00 --					

CANADA. *Meteorological Service of Canada, Victoria*

			H. m. s.	Sec.	μ	μ	Km.	
1924 3		L	12 14 39	15				N-S component, not visible.
E		M	12 18 29	15		2		
		F	12 21 51					
11		L	?7 07 55	26				
		M	7 15 27	20		6		
E		F	7 59 05					
		L	?7 08 05	30				
N		M	7 20 23	18	2			
		F	7 55 05					
13		M	23 42 29	20		2		
E		F	(?)					
		M	23 36 00	20	1			
N		F	(?)					
15		P	13 10 33	5				
		L	13 11 28	12				
E		M	13 11 55	12		6	480	
		F	13 18 03					
		P	13 10 43	5				
N		L	13 11 33	12				
		M	13 12 31	10	5		450	
		F	13 17 33					
16		P	0 43 38	10				
		S	0 50 23	12				
E		L	1 03 03	20				
		M	1 09 15	15		4	5,050	
		F	1 26 03					
		P	0 43 38	10				
		S	0 50 28	12				
N		L	(?)					
		M	1 10 28	15	1		5,140	
		F	(?)					
18		L	17 56 10	25				
E		M	17 58 20	20		2		
		F	18 14 10					
N		P	17 27 50	6				
		L	17 57 10	25				
		M	18 00 20	20	6			
		F	18 16 30					
19								
		P	7 24 04	10				
E		L	7 43 24	20				
		M	7 55 31	20		5		
		F	8 14 59					
		P	7 23 39	10				
		L	7 43 29	20				
N		M	7 56 59	20	6			
		F	8 14 59					

TABLE 2.—*Instrumental seismological reports, February ,1924*—Con.

CANADA. *Metrological Service of Canada, Victoria*—Continued

1924			H. m. s.	Sec.	μ	μ	Km.
21		P	13 19 04	8			
		L	13 21 46	12			
E		M	13 23 19	10		9	1,550
		F	13 28 04				
		P	13 19 04	8			
N		L	13 20 24	12			
		M	13 23 09	8	13		730
		F	13 27 04				
22		P	10 52 06	6			
		L	10 53 48	12			
E		M	10 55 18	10		9	940
		F	11 05 06				
		P	10 52 06	6			
		L	10 53 41	14			
N		M	10 56 06	10	14		880
		F	11 06 06				
24		P	5 46 33	2			
		L	5 47 35	12			
E		M	5 50 29	10		71	560
		F	6 11 07				
		P	5 46 33	4			
		L	5 47 37	12			
N		M	5 51 22	10	76		580
		F	6 10 42				
24		L	8 10 08	10			
		M	8 12 38	10		5	1,430
E		F	8 17 08				
		L	8 10 08	10			
N		M	8 13 14	8	7		1,810
		F	8 15 28				
25		L	19 38 06	10			
		M	19 38 51	8		5	410
E		F	19 40 46				
		L	19 38 21	10			
N		M	19 38 51	8	2		270
		F	19 40 51				

No earthquakes were recorded during February, 1924, at the following stations:

ARIZONA. *U. S. C. & G. S. Magnetic Observatory*, Tucson.
COLORADO. *Regis College*, Denver.
MARYLAND. *U. S. C. & G. S. Magnetic Observatory*, Cheltenham.
PORTO RICO. *U. S. C. & G. S. Magnetic Observatory*, Vieques.
VERMONT. *U. S. Weather Bureau*, Northfield.

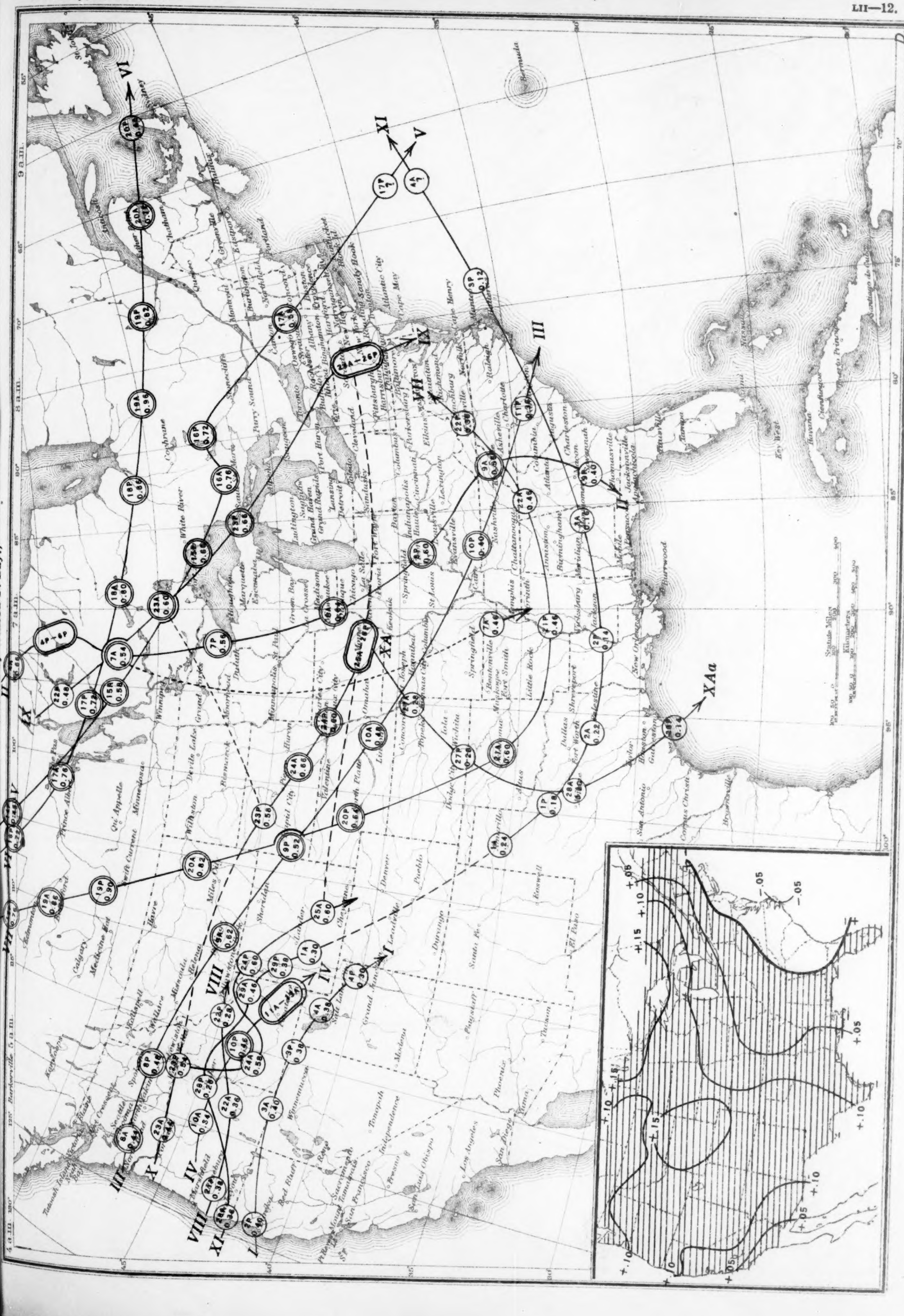
Reports for February, 1924, have not yet been received from the following stations:

DISTRICT OF COLUMBIA. *Georgetown University*, Washington.
MASSACHUSETTS. *Harvard University*, Cambridge.
MISSOURI. *St. Louis University*, St. Louis.
NEW YORK. *Cornell University*, Ithaca; *Fordham University*, New York.

TABLE 3.—*Late reports (instrumental)*

DISTRICT OF COLUMBIA. *Georgetown University*, Washington

1924			H. m. s.	Sec.	μ	μ	Km.	
Jan. 1		i_N	3 10 47					i_N is possibly S_N.
		eL_N?	3 14 12					
		F	3 25 ..					E-W does not show.
4		e_E	22 01 16	10				Very heavy micros.
		e_N	22 01 10					
		eL_E	22 3 18	10				
		eL_N	22 3 24	10				
		L_E	22 05 06	10				
		L_N	22 05 26	10				
		F	.. .. ..					Micros.
5		e_E	18 45 ..					Very heavy. micros.
		e_N	18 45 ..					
		i_E	18 46 ..					
		i_N	18 46 ..					
		F	19 (*ca.*)					
14		eP_N?	21 01 49					Do.
		i_E	21 08 00					P Possibly sooner.
		i_N	21 08 00					E-W shows no P.
		eS_E	21 14 31					
		eS_N	21 14 31					
		L_E	21 53 23	18				
		L_N	21 56 16	21				
		F	21 30 ..					
21		eP_E	2 05 24					Rest of phases masked in micros.
		iP_N	2 05 24					
		eS_E	2 13 19					
		L_E	2 31 57					
25		e_E	6 12 40					Very heavy micros.
		e_N	6 12 40					
		eL_E?	6 26.4					
		eL_N?	6 26.4					
		F	.. .. ..					Micros.
29		eP_E	2 05 47					
		iP_N	2 05 47					
		eS_E	2 14 40					
		iS_N	2 14 43					
		eL_E	2 36.3	16				
		eL_N	2 36.1					
		F	2 52 ..					
30		eP_E	20 59 11					Do.
		iP_N	20 59 07					
		S_E	21 04 57					
		S_N	21 04 57					
		eL_E	21 8.2	9				
		eL_N	21 8.2	9				
		F	21 25 ..					
31		e_E	1 16 37					Do.
		i_N	1 16 38					
		F	1 26 ..					Possibly at 1-08-56.


Departure of Monthly Mean Pressure from Normal.
(Plotted by Wilfred P. Day.)

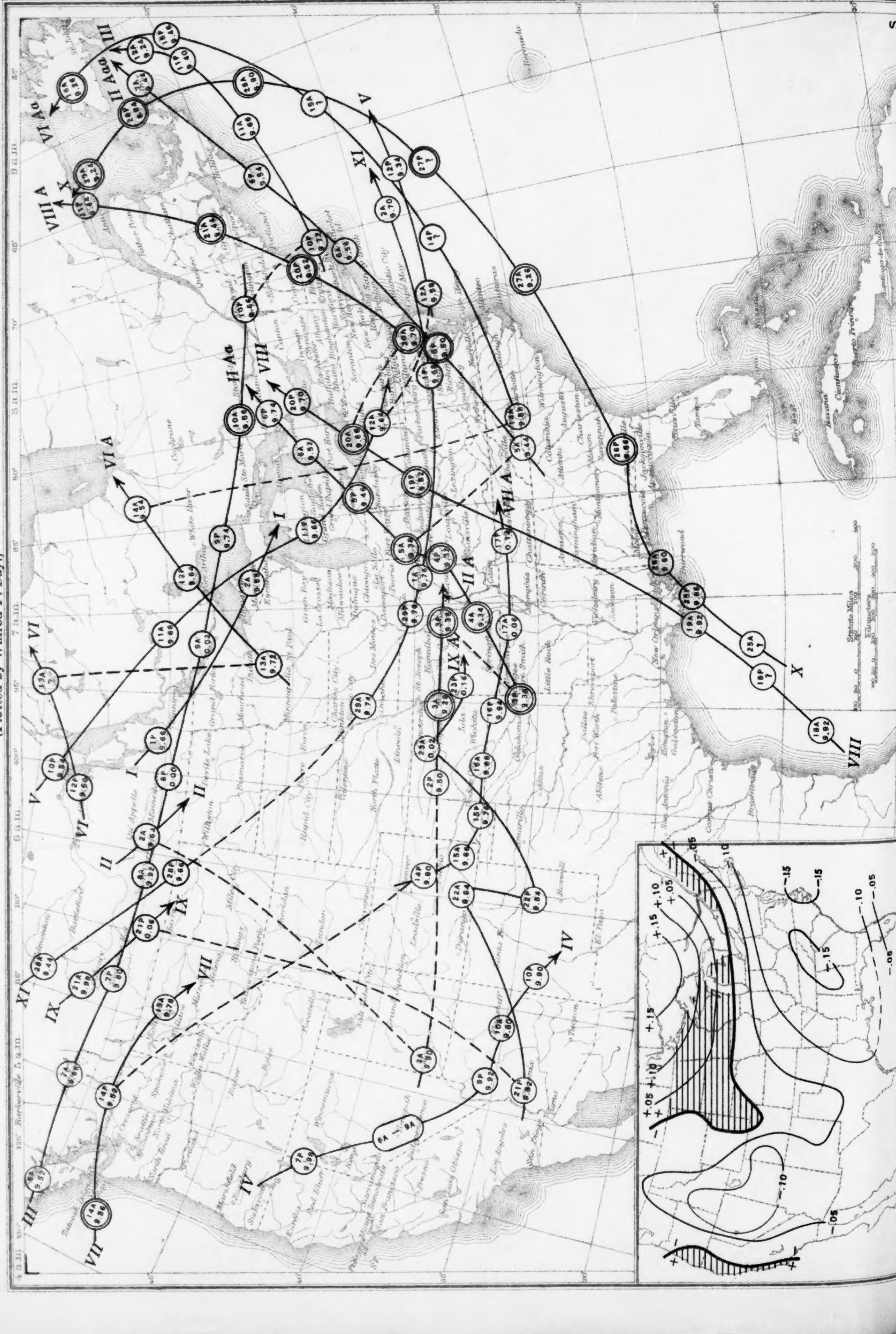


Chart II. Tracks of Centers of Cyclones, February, 1924. (Inset) Change in Mean Pressure from Preceding Month.
(Plotted by Wilfred P. Day.)

Chart III. Departure (°F.) of the Mean Temperature from the Normal, February, 1924.

Chart IV. Total Precipitation, Inches, February, 1924. (Inset) Departure of Precipitation from Normal.

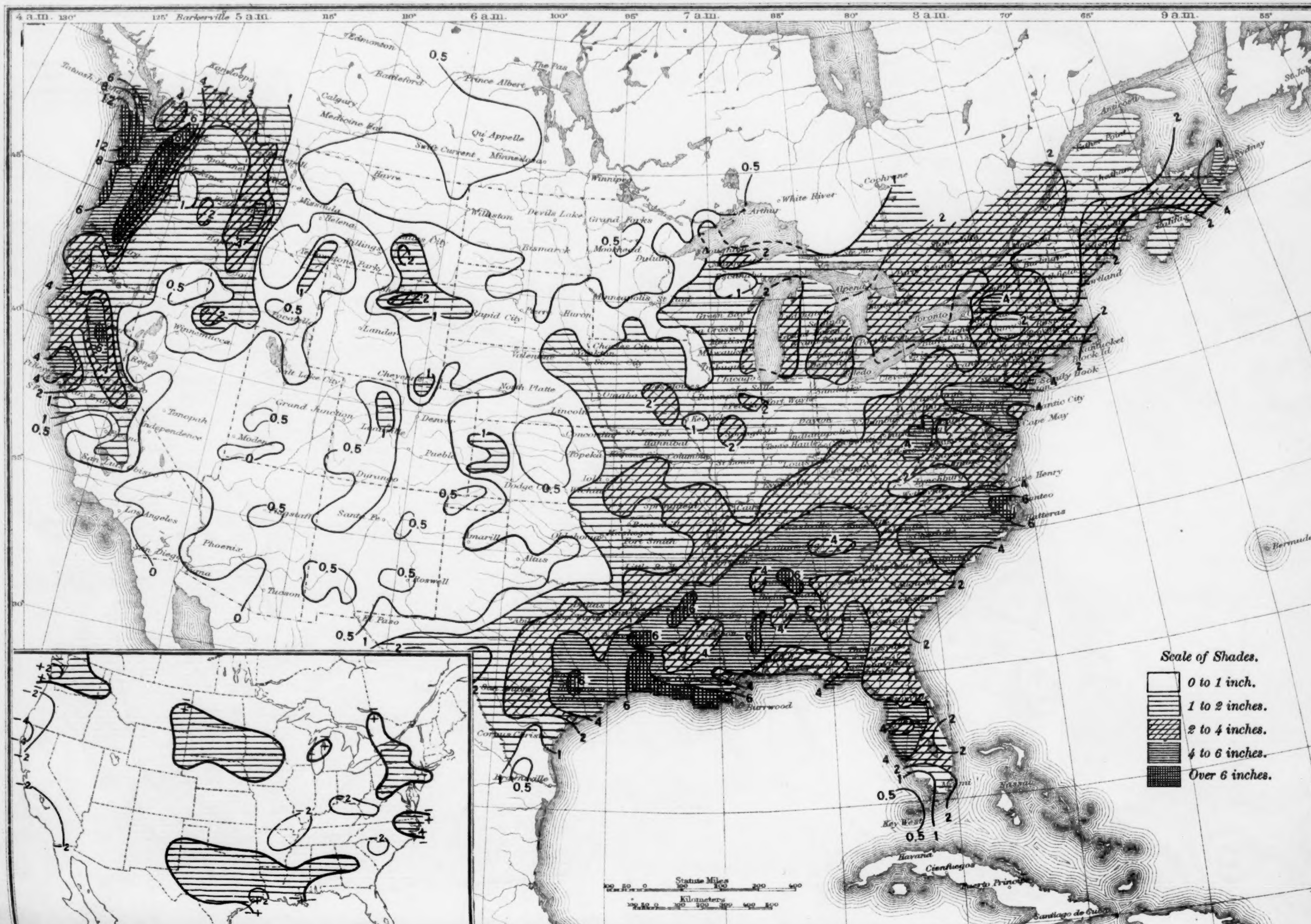


Chart V. Percentage of Clear Sky between Sunrise and Sunset, February, 1924.

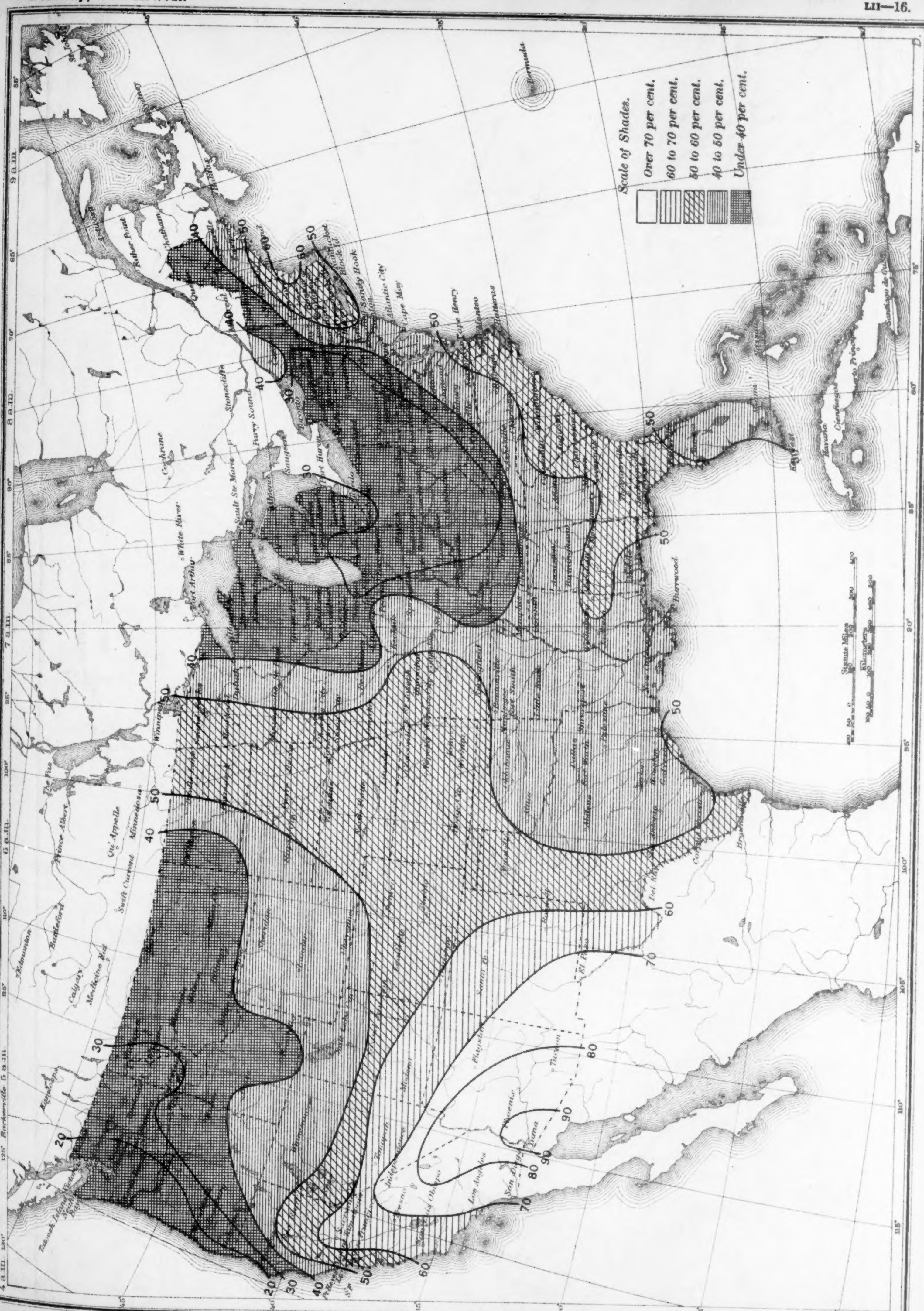
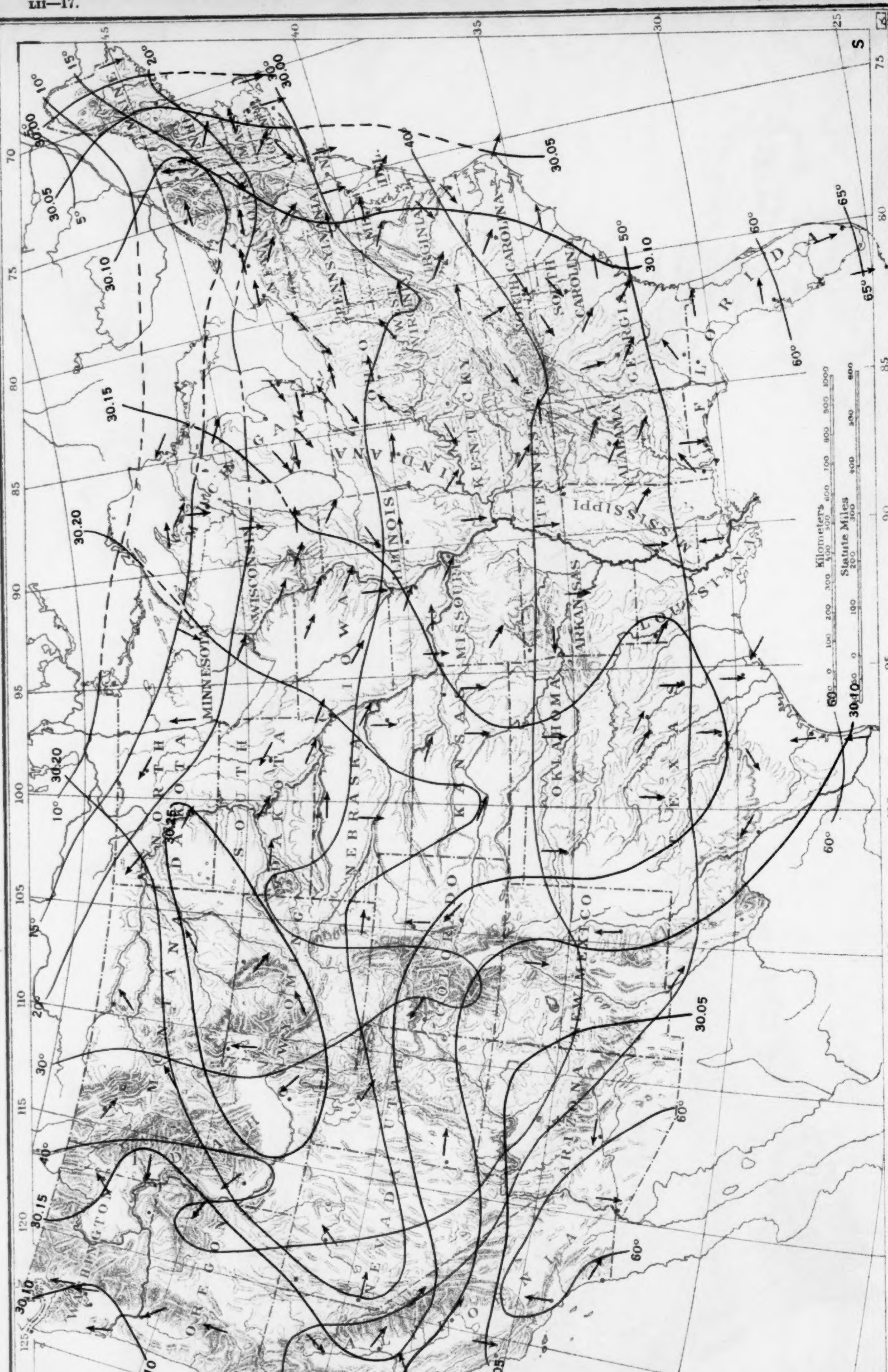


Chart V. Percentage of Clear Sky between Sunrise and Sunset, February, 1924.

Chart VI. Isobars at Sea-level and Isotherms at Surface; Prevailing Winds, February, 1924.



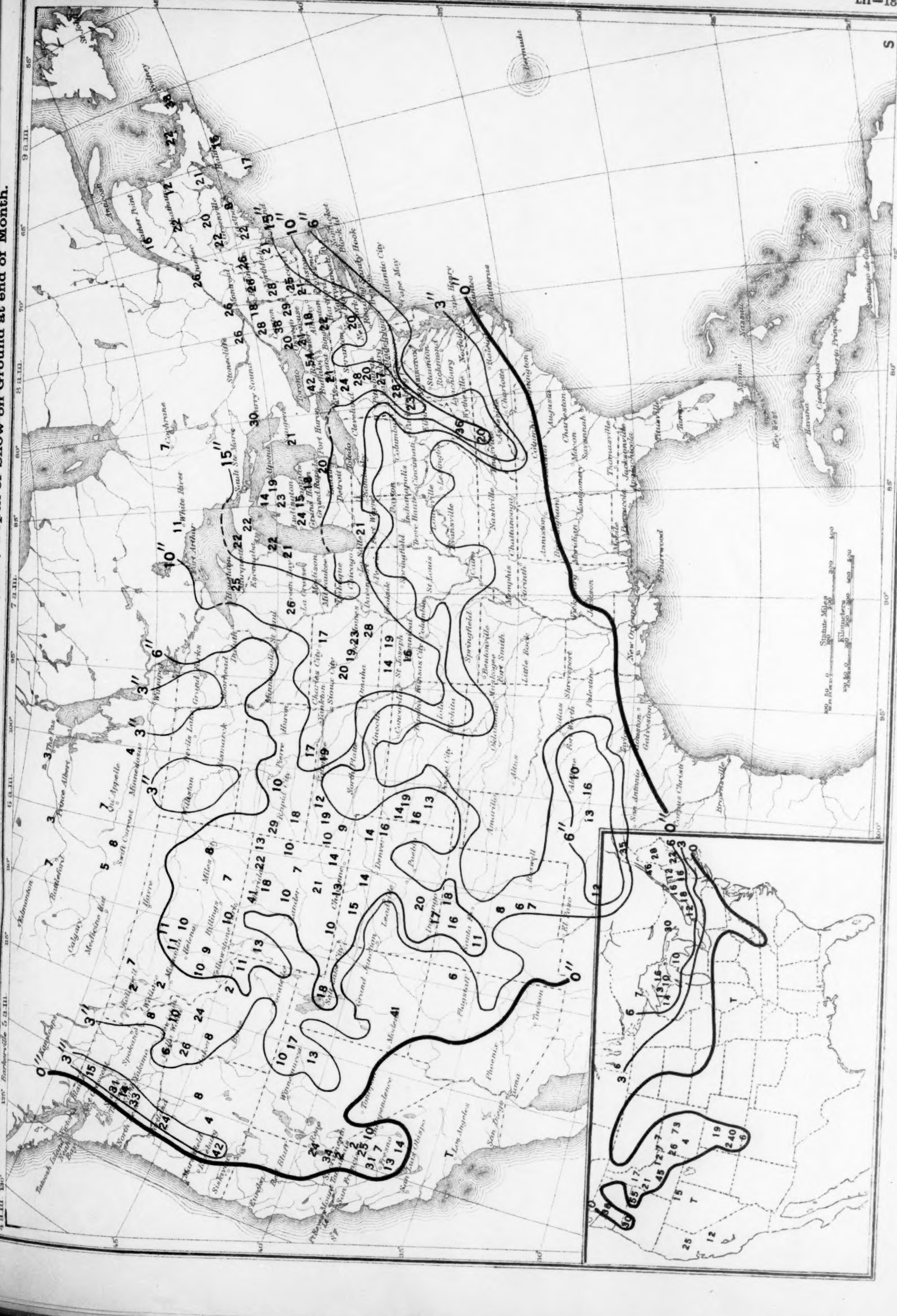


Chart VII. Total Snowfall, Inches, February, 1924. (Inset) Depth of Snow on Ground at end of Month.

(Plotted by F. A. Young.)

North Atlantic Ocean, February 5, 1924.
(Plotted by F. A. Young.)

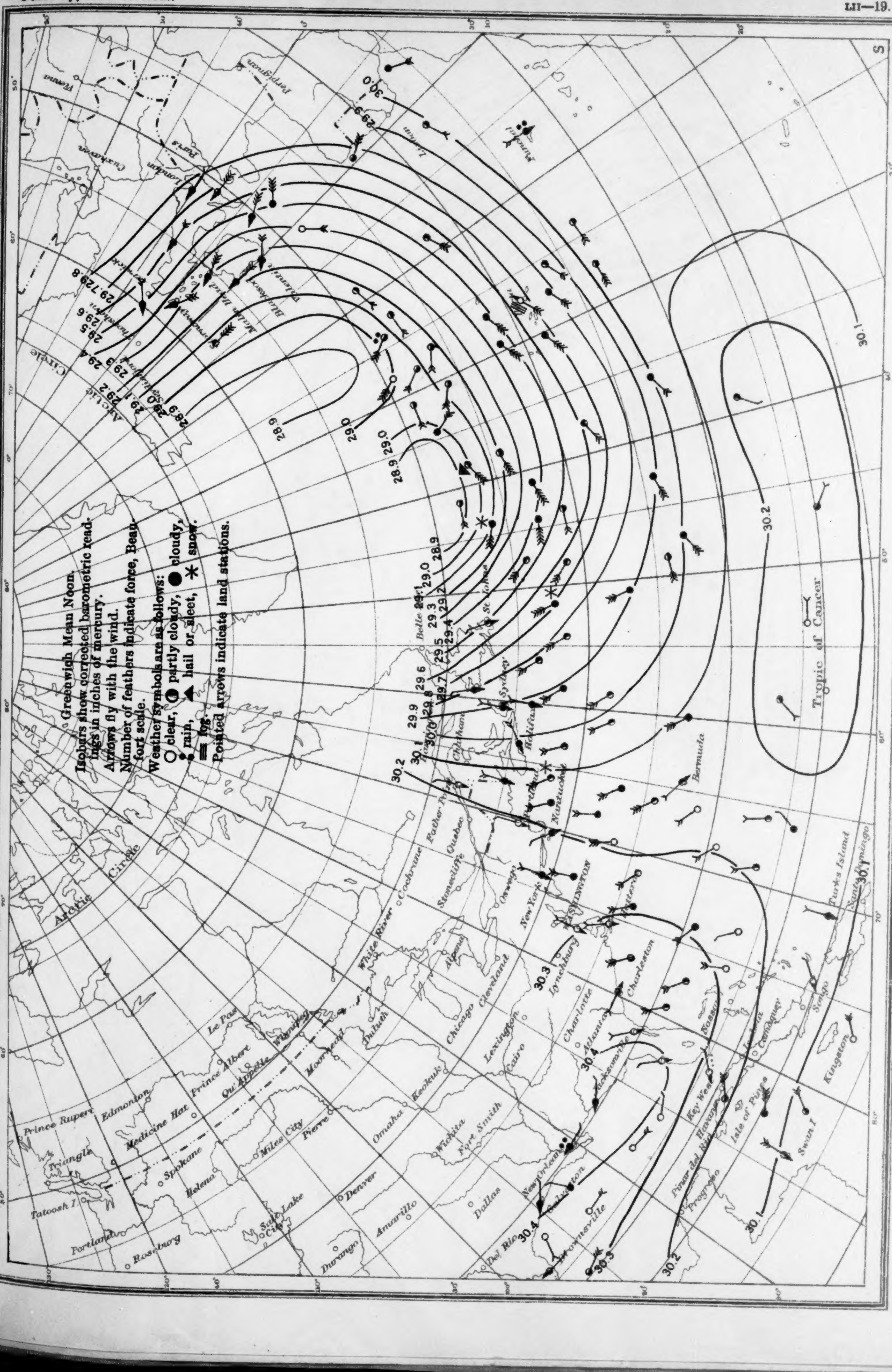
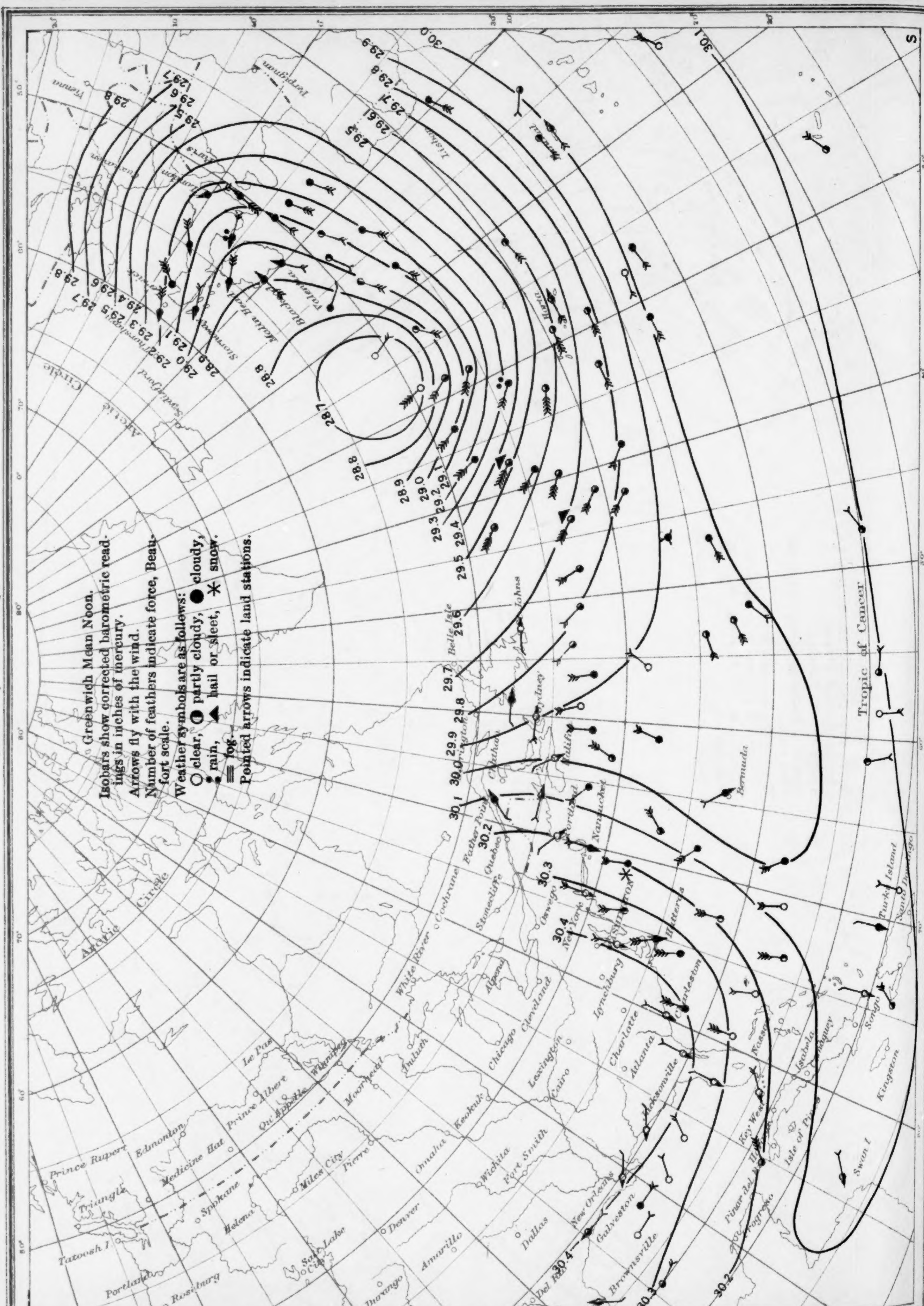


Chart IX. Weather Map of North Atlantic Ocean, February 9, 1924.
(Plotted by F. A. Young.)



Weather Map of North Atlantic Ocean, February 10, 1924.

(Plotted by F. A. Young.)

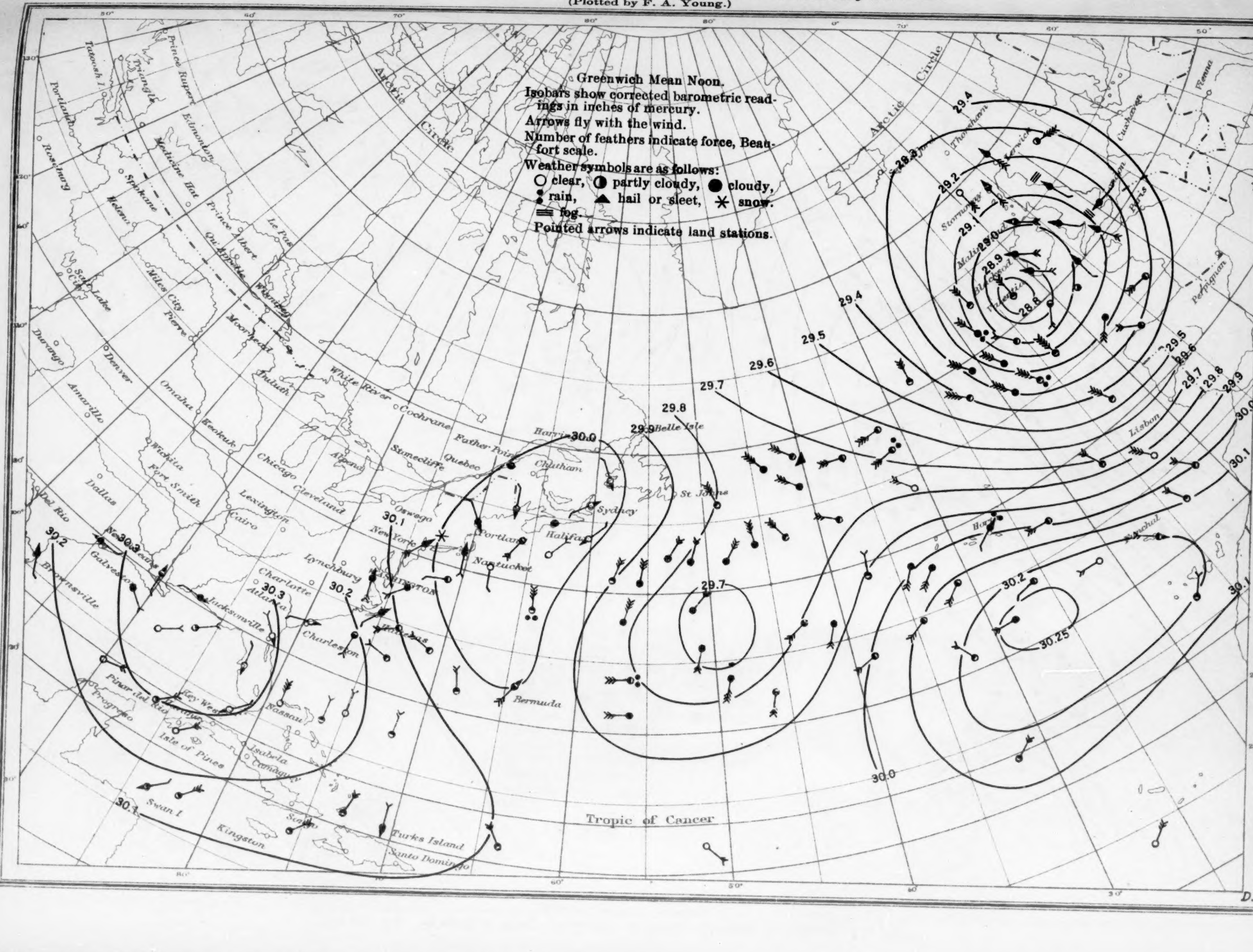
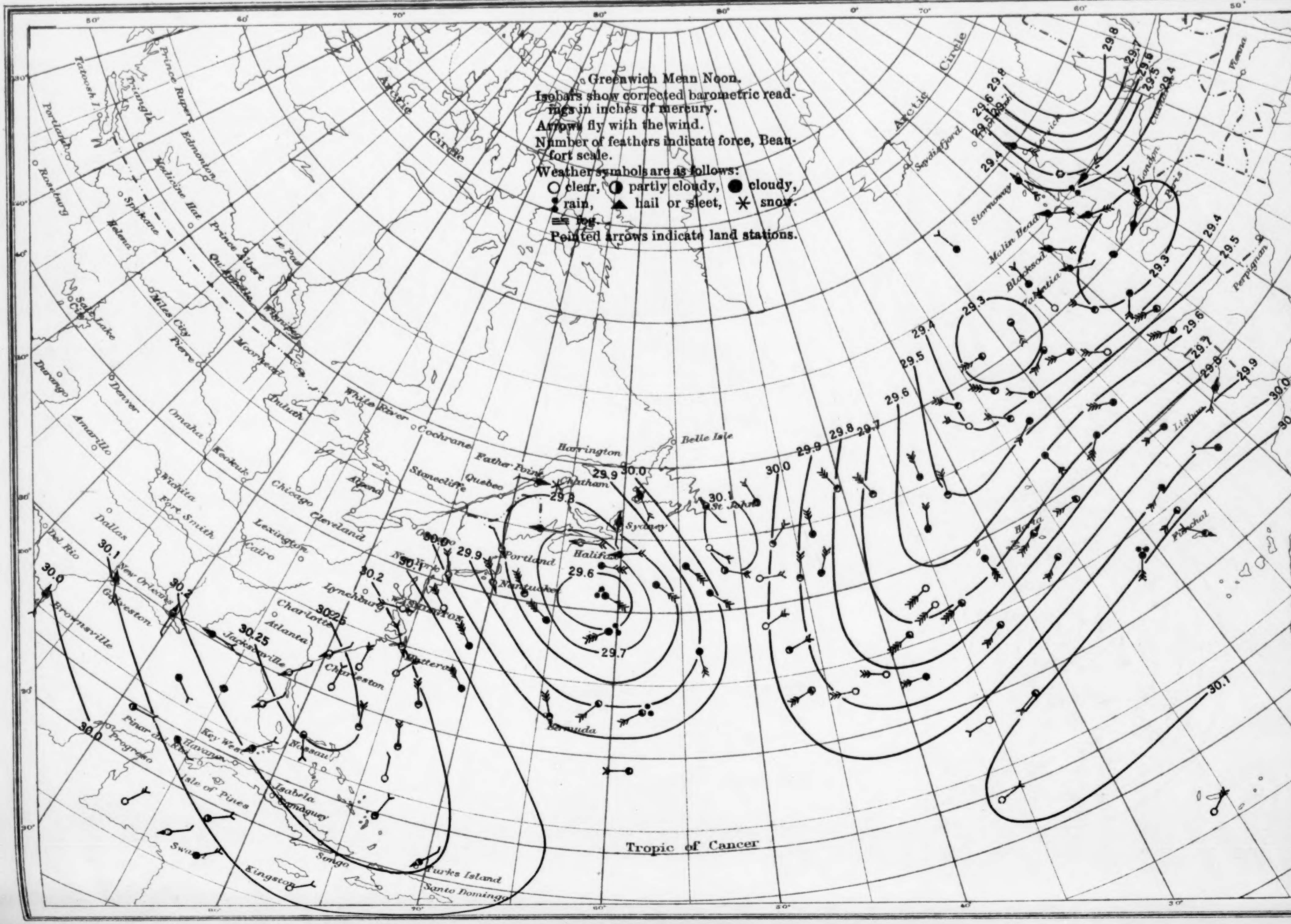


Chart XI. Weather Map of North Atlantic Ocean, February 11, 1924.

(Plotted by F. A. Young.)



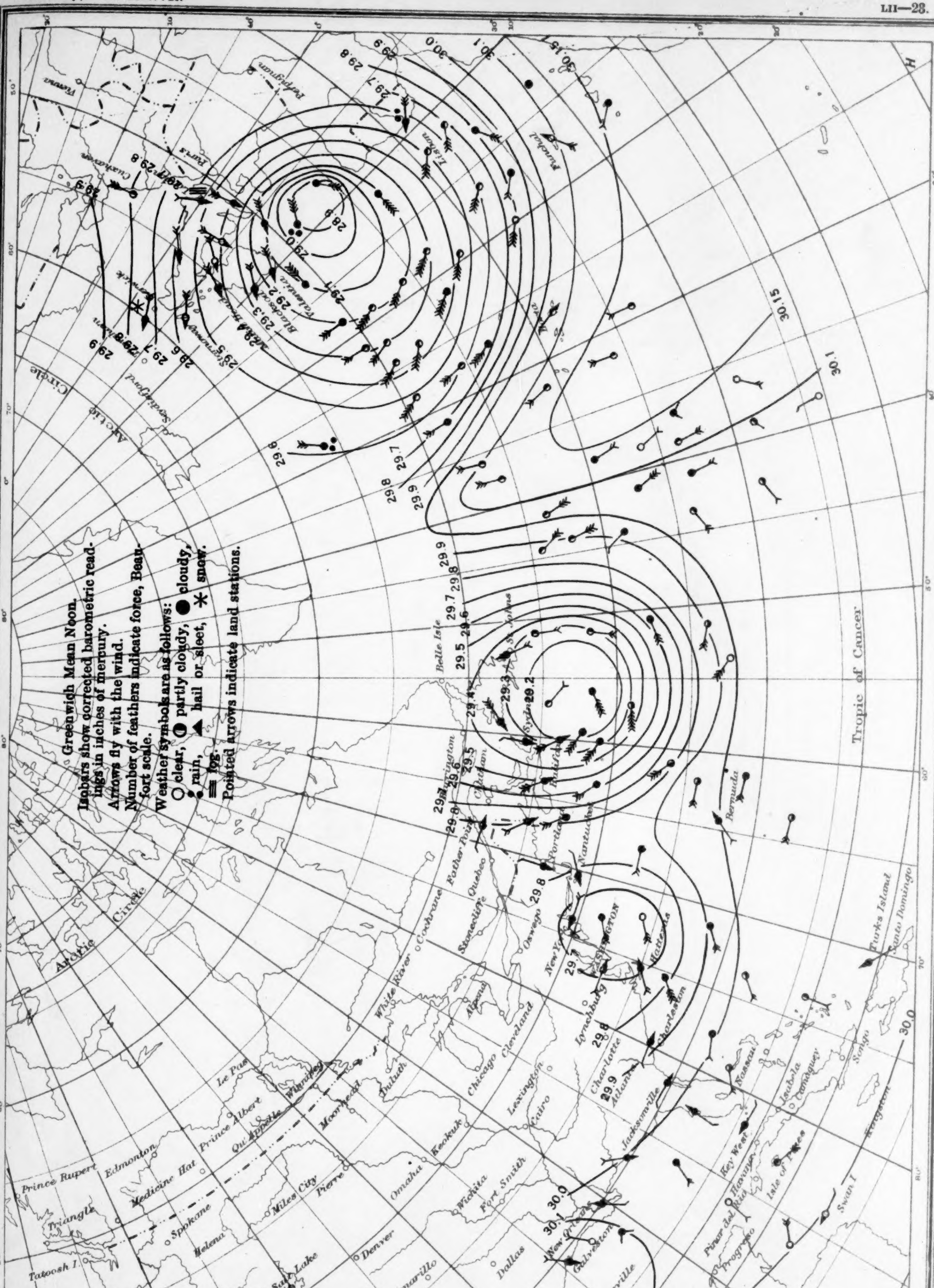


Chart XII. Weather Map of North Atlantic Ocean, February 12, 1924.
(Plotted by F. A. Young.)

Chart XIII. Weather Map of North Atlantic Ocean, February 13, 1924.

(Plotted by F. A. Young.)